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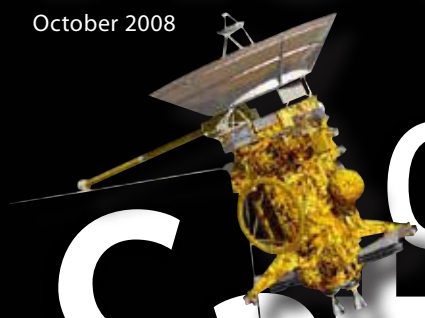

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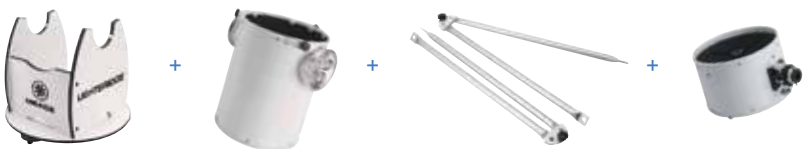

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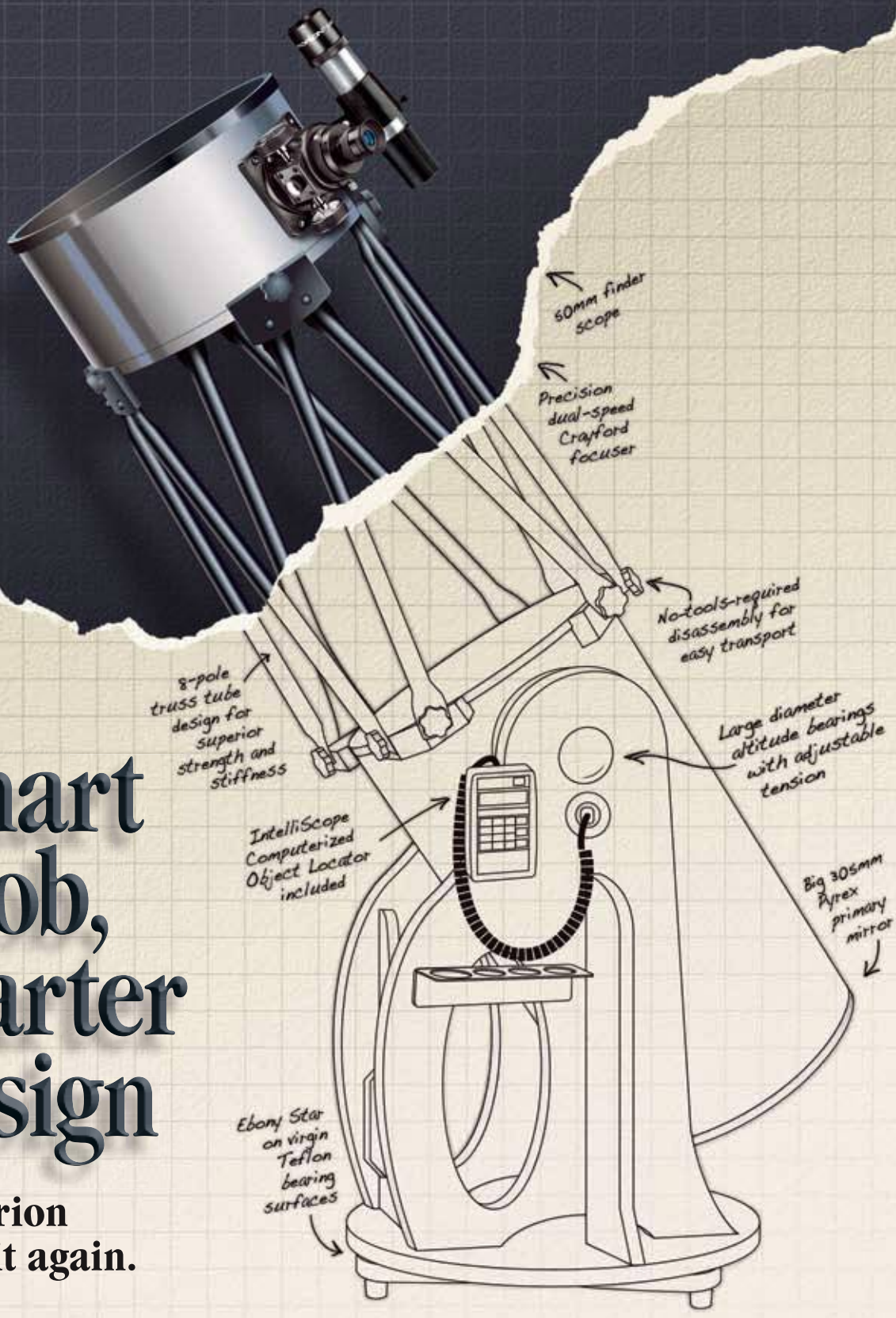
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This month in *Astronomy*

Understanding our "sister planet"

by David J. Eicher

Few things transfix sky watchers like Venus, dazzling us as it hangs above the horizon. This most familiar of all naked-eye planets is perhaps the least familiar planet in conveying its history to us. While most of our planetary brethren had volatile beginnings and have been relatively stable since, Venus provides a stark exception.

About a half billion years ago, catastrophic events dominated the planet as volcanic energy spewed forth, and, in short, the planet turned itself inside out. Since the discovery of Venus' volcanic resurfacing and the realization that its surface is relatively young, planetary scientists have yearned to know why and how this happened.

Launched in 2005, the European Venus Express mission is the latest spacecraft to place Venus under scrutiny. Since entering orbit in spring of 2006, Venus Express has been collecting data, and it's time we bring you an important update on the findings.

In "Taking Venus by storm," science writer Robert Zimmerman explores the craft's accomplishments. As Zimmerman reports, the buzz in the science community is great. "Venus Express is allowing us to get a more sophisticated, in-depth picture of what's really going on," says David Grinspoon, a Venus researcher at the University of Colorado and Venus Express team member. "Seeing the patterns and the long-term changes in Venus' climate is going to allow us to do comparative planetology," he says, "which will ultimately shed light back on Earth's climate and how it works and changes."

This year, Venus Express scientists have made some exciting proclamations. They announced the discovery of hydroxyl in Venus' atmosphere. This discovery joins a list of findings that include detecting lightning in Venus' atmosphere, mapping the planet's global weather patterns, discovering peculiar hazes that form on Venus, and logging changes in the planet's sulfur dioxide distribution.

All these data have implications for Earth, as well as purely for our sister. "Venus Express has already shown us that Venus is much more earthlike than once thought," says Giuseppe Piccioni of the Instituto di Astrofisica Spaziale e Fisica Cosmica in Rome. "The detection of hydroxyl brings the planets a step closer."

This month's issue also provides a preview of the next, and final, Hubble Space Telescope servicing mission, set for October. In "How we'll fix Hubble," Senior Editor Richard Talcott describes the mission, details the instrument changes, and previews the celebrated space telescope's final days.

NASA plans to keep Hubble operating through 2013, when the James Webb Space Telescope goes on-line. But the former, the workhorse of the last 15 years of astronomical and cosmological discoveries, will ultimately fall into Earth's atmosphere and disintegrate.

The story of the final shuttle mission to Hubble, which will take place a short time after you read this, will be dramatic. But Hubble itself, as Talcott writes, will keep chugging along for a while yet, continuing to dazzle and outperform expectations. After that initial stumble with the optical blunder, who could have then guessed that Hubble's life story would end up being so spectacular?

Yours truly,

David J. Eicher
Editor

Astronomy

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Could Earth have two Moons?

Computer simulations suggest Earth could have evolved two moons after collision with a Mars-sized body billions of years ago. Lick Observatory

I enjoyed the information about Robin Canup's computer simulations of the Moon's birth in "Earth's troubled adolescence" (May 2008). It made me wonder what other results her simulations could give rise to. For example, if the Mars-sized impactor had been bigger, or if Earth had a different rotation, could we have ended up with two moons? — **Roger Stokes,** San Diego, California

A larger impactor and/or a more sharply angled collision tends to produce a larger final moon. In the extreme case of a grazing impact by an impactor comparable in size to the protoplanet it strikes, a very large moon can result.

With Earth, it is difficult to end up with two moons. Sometimes multiple moons result from the initial stage of debris accumulation after the impact. As the moons interact with Earth, their orbits expand — just as the Moon's orbit continues to expand today. During the expansion, the moons typically collide with each another. This would then cause them to eventually merge into a single moon. Or, one of the moons can be destroyed subsequently in a collision with Earth. — **Robin Canup,** Southwest Research Institute, Boulder, Colorado

iStarParty vision

In the February 2008 "This month in *Astronomy*," Editor Dave Eicher asked for opinions from amateur astronomers about the magazine's proposed Internet-based star party, iStarParty. I think the idea is wonderful.

Talk to all the other public observatory sites — new, old, and still on the drawing boards — and let's pull together so the world finally has a virtual place to explore space. I believe we were created in part as a way for the universe to know itself. Why not create a way for that to actually happen? — **James Lehr Miller,** Tucson, Arizona

Thanks for your interest in iStarParty. We are continuing to develop the idea. In the meantime, Microsoft Worldwide Telescope [www.worldwidetelescope.org] has, at least in part, begun to fulfill the idea of providing a way to connect stargazers to telescopes via the Internet. — **Dave Eicher,** Editor

In praise of Yerkes

Thank you for highlighting Yerkes Observatory and other historic facilities in "How historic observatories will survive" (April 2008). While I can't speak for other observatories, I am very familiar with Yerkes.

Far from being obsolete, the observatory provides teachers with what they need to teach astronomy. It offers a meeting place and forum for scientists to interact with teachers and children. Yerkes funds numerous astronomy clubs for students, including a program for blind children.

There is nothing obsolete, either, about viewing, say, a globular cluster through a 40-inch refractor — the largest in the world — or learning about the universe through hands-on experience. It's inspiring to know you are standing in the same place where Einstein, Hubble, and Yerkes once stood.

Modern astronomy may have "moved on," but I contend that Yerkes Observatory has more than kept pace. Thank the stars it wasn't sold! — **Laura DiMartino,** Pershing Elementary School, Joliet, Illinois

Dreyer didn't do it

In Stephen J. O'Meara's "How to find a Space Needle in a haystack" (April 2008), he says John L.E. Dreyer misidentified the Pencil Nebula as a galaxy in his 1888 *New General Catalogue of Nebulae and Clusters of Stars*. How could something have been classified as a galaxy when galaxies outside the Milky Way weren't known to exist until the 1920s? — **Eric O'Reilly,** Edmond, Oklahoma

That incorrect statement was the result of an editorial error, not a lapse in Mr. O'Meara's knowledge of astronomy history. The Pencil Nebula was first erroneously categorized as a galaxy in the 1973 Revised New General Catalogue *(*RNGC*), but not by Dreyer.* — **Astronomy Editors**

AAVSO and science

In Glenn Chaple's article "Reap the awards of amateur astronomy" (April 2008), he left out an important distinction between the awards mentioned.

Many certificate programs help to challenge and educate us. However, observations reported to the American Association of Variable Star Observers lets you take the next step by contributing real scientific data used by professional astronomers. How rewarding it is that collaboration between amateurs and professionals is encouraged. — **Bill Lomaka,** Rochester Hills, Michigan

CORRECTIONS

In "Binocular telescope snaps first image" (June 2008, page 21), the distance to NGC 2770 should be 102 million light-years, not 102 light-years. In August 2008's "Ask Astro," the photo of an astronaut on the Moon shows Eugene Cernan, not Harrison Schmitt. — **Astronomy Editors**

We welcome your comments. Send letters to Astronomy *Letters, P. O. Box 1612, Waukesha, WI 53187; e-mail to letters@astronomy.com. Please include your name, city, state, and country. Letters may be edited for space and clarity.*

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October web extras

Go beyond the stories printed in this issue with these subscriber-only features. Monthly web extras bring you additional research, interviews, photographs, and animations that our editors turned up while creating the magazine stories.

"Cassini phase 1" p. 34
View some of Cassini's best images of Saturn.

"Ask Astro" p. 72
Is orbiting space junk a threat to the International Space Station?

"Your 20-year solar eclipse planner" p. 74
Get a preview of the 2009 solar eclipse in China.

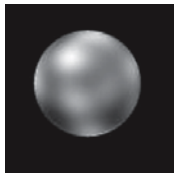
"Inside Arizona's meteorite treasure chest" p. 80
See more images of meteorites.

"See red stars in Cepheus" p. 84
Find more red stars you can observe.

"The house of Cepheus" p. 85
Discover additional observing targets in Cepheus.

This month's top blogs

Editors put their spin on current events in the staff blog. You can share your opinions on news headlines and popular culture, too.



1 PLUTO HAS BEEN PLUTOIDED!
From planet to dwarf planet to plutoid, where will the reclassifying of Pluto end? **BY DANIEL PENDICK**

2 HOW TO MAKE A BAD FIRST IMPRESSION
The University of Leicester is sending junk food ads to extraterrestrials. **BY JEREMY MCGOVERN**

3 MOONDUST MIRRORS
These new telescope mirrors may lead to building scopes on the Moon. **BY FRANCIS REDDY**

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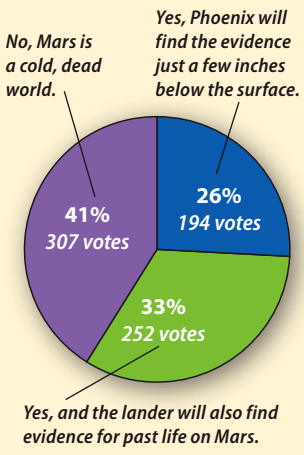
Featured video

ITALY: GALILEO'S TUSCAN SKY TOUR
Editor David J. Eicher previews *Astronomy*'s 2009 trip to celebrate the telescope's 400th anniversary.

Online poll results

Will NASA's Phoenix lander find evidence of a habitable zone on Mars?


No, Mars is a cold, dead world.
Yes, Phoenix will find the evidence just a few inches below the surface.
41%
307 votes
26%
194 votes
33%
252 votes
Yes, and the lander will also find evidence for past life on Mars.

Total votes: 753

Join the fun! You'll find the weekly question on the lower right side of the home page.

Globular cluster M4 in Scorpius

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TOURING SCORPIUS
Senior Editor Michael E. Bakich takes you on a tour of the constellation. Also, watch a video tour.

THE FAULKES TELESCOPE PROJECT AND ASTEROID 2008HJ
Amateur astronomer Richard Miles measured the fastest spinning object in our solar system.

OUT-OF-THIS-WORLD AWARD
Jim Zebrowski of the Aldrich Astronomical Society, 2007's recipient of the award, talks about his group.

Far left, clockwise: NASA-JPL; NASA; NOAO/AURA/NSF

Cool blue to hot stars

Once you go beyond the friendly confines of the Milky Way Galaxy, it's hard to see individual low-mass stars. Images of even nearby galaxies, like the 160,000-light-year-distant Large Magellanic Cloud (LMC), chiefly show the massive blue stars that generate prodigious amounts of light. This Hubble image of the LMC star-forming region LH 95 goes deeper. Although massive stars still stand out, the abundant faint pinpricks you see mark newly formed stars smaller than the Sun. The blue haze shows vestiges of the cool, dusty molecular cloud from which the stars formed. The dust absorbs blue light from more distant stars and galaxies, giving them a redder tint. NASA/ESA/D. A. Gouliermis (MPIA)

Strange Universe

by Bob Berman

Astro-humiliation

Reminiscing about moments of astronomy-related shame and embarrassment.

Astronomy, embarrassing? Believe it. And what better authority than someone who's played the fool in each phase of his career.

As a kid, when I still lived in the city, I set up my little 2.4-inch refractor on the sidewalk. One cold night the streets were empty. Then, from around the corner, I heard slow footsteps. I kept gazing into the eyepiece, the steps getting louder. I was spooked. Finally, gathering my courage, I looked up, and came face to face with . . . a little old lady.

"Don't set it off now, sonny!" she commanded. I stammered something, but she wouldn't believe the tube I was bending over wasn't fireworks.

A few years later, I carried the scope to a flat roof, joined by my high school's most beautiful girl. I'd always been intimidated by her. Peering intently through the eyepiece, I beckoned her to come take a look. But my blindly gesturing hand instead reached straight to her chest. Bam, direct hit, solid. It was so awkward, I wanted to be transported to the Moon.

Back then, I memorized everything. In college, I put countless tables in my head, and they still come in handy at lectures. The martian day? Oh it's 24 hours, 37 minutes, 23 seconds. But occasionally someone will ask something that draws a blank. If this happens on live radio, it's terrifying.

A sophisticated caller asked whether airglow is caused by sunlight or the solar wind. Hmmm. Auroras are produced by the latter, and isn't airglow a miniature aurora? I said charged particles — the solar wind. I was dead wrong. Later I felt like an idiot.

But not as much as the time, during my 17 years as a *Discover* columnist, I used an erroneous eclipse table and thus said that the 1998 eclipse would be visible from St. Kitts. A reader later sent us a letter. He'd booked his trip based on my "facts," but the eclipse was only "partial" on that Caribbean island. I still feel bad. It was a valuable lesson on the importance of fact-checking.

At the observatory, I was gazing through the eyepiece looking for M51, surrounded by a group of my students. But I saw nothing through the 16-inch Cassegrain reflector as I fumbled with the slow-motion controls. Finally, a student pointed to the dust cap, which was still on. Everyone giggled. Bob Berman, observatory director — and moron.

Everyone giggled. Bob Berman, observatory director — and moron.

OK, here's the very worst. It came during a luncheon with George Abell, then chair of astronomy at UCLA. Many galaxy clusters are named for him. I used his textbook when I taught college astronomy. I'd admired him for decades. Abell and I were chatting about pseudoscience. I said, "We all have to decide where to draw the line between open-mindedness and gullibility."

It was a great line my friend Chris had uttered a month earlier. But Abell suddenly stopped eating, looked at me oddly, and muttered, "I think that's been said before."

Back home after the conference, I asked Chris about the remark: "You did originate that yourself, didn't you?"

"No," he said, "I read it in one of George Abell's books." I had presented the great astronomer's own line to him as if it were my original thought! Ouch.

Sometimes I've had to relieve someone else's embarrassment. In 1980, the Indian government invited me to use its largest telescope, located near Naintal in the Himalayan foothills. A staff astronomer accompanied me. I was visiting for fun, not research, so I suggested some visual targets, starting with the Trapezium sextet of stars in Orion.

The 40-inch Cassegrain whirred and slewed, the dome rotated, and then everything stopped. My host peered into the eyepiece, and peered some more. I gazed up through the dome's slit and immediately saw we were nowhere near Orion. But was it my place to tell him he'd blown it? I stayed quiet. Turned out, a power failure earlier that day — which in India are as common as mangos — had thrown all the electronics into never-never land.

When he realized the problem, he thought all was lost. As in another observatory when the same trouble arose, the staff was reluctant to release the axes and manually find the object. To them, visually locating anything seemed as intimidating as hand-steering a spacecraft to the Moon. Gone was the ancient art of knowing the sky. But I diplomatically said nothing.

And then there was the time a person kindly drove me back to a lonely rural airport late at night after I'd given a talk. When they'd driven off, I turned to find all the gates locked. I could see my plane but couldn't get to it. The dark, chilly, deserted scene was downright creepy. It was the middle of nowhere.

Climb the barbed wire fence, with all my lecture gear, like a terrorist?

Yes. Exactly. And so exits the dignified astronomer.

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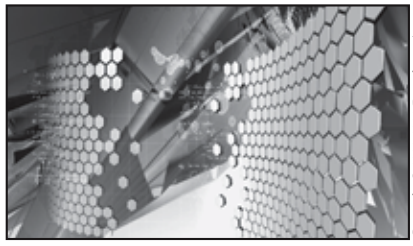

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About Your Professor

Professor Steven Strogatz is the Jacob Gould Schurman Professor of Applied Mathematics and Professor of Theoretical and Applied Mechanics at Cornell University. He received his Ph.D. from Harvard University. Professor Strogatz is the author of *Nonlinear Dynamics and Chaos*, the most widely used textbook on chaos theory. In 2007, he received the Communications Award—a lifetime achievement award for the communication of mathematics to the general public—from the Joint Policy Board for Mathematics, which represents the four major American mathematical societies.

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Secret Sky

by Stephen James O'Meara

The Pit and the Pendulum

Stars' apparent motions mark the passage of time and important life events.

"There was something, however, in the appearance of this machine which caused me to regard it more attentively. While I gazed directly upward at it . . . I fancied that I saw it in motion."
— Edgar Allan Poe, The Pit and the Pendulum

Last March, I watched the dead come to life. On the evening of the 13th, Halemaumau, the summit crater of Hawaii's Kilauea Volcano, spewed incandescent gas into the night air for the first time in more than a quarter-century. Seven days later, the crater erupted for the first time since 1924. Like the periodic return of Halley's Comet, the recurrence of explosive activity at Kilauea may be a once-in-a-lifetime event.

Aside from reminding me of the many cycles in nature, something else happened during this historic event. On the night of March 18, I photographed the stars arching over Kilauea's smoking fire pit like the upside-down pendulum of some great clock. During these long exposures, I suddenly became aware of the slow but relentless passage of time.

It's not something easily noticed. Perhaps that's because the fast pace of today's world fathers short attention spans. But if you'd like to step out of the fast lane, try looking at the stars and waiting for one to move. It requires a bit of patience and, of course, time.

The tree of time

In this case, we're not really seeing the stars move at all, but Earth rotating on its imaginary axis. Earth spins once every 24 hours — 23 hours, 56 minutes, and 4 seconds, to be exact. As a result, the stars appear to move across the sky at a rate of 15° every hour, or 1° every 4 minutes.

One degree is equal to the apparent diameter of two Full Moons placed side by side. And while that may seem like a sizable chunk of celestial real estate, it's only 1/360th of the sky's circumference. You can cover that same area of sky with a fingertip held at arm's length.

Most observers become aware of star movement only when entire constellations move significantly with respect to familiar foreground objects, like houses or stands of trees. But seeing a star move in real time is a serious challenge. The trick is to sit down, make yourself comfortable, and position a bright star next to an artificial horizon.

I used a tree trunk that was conveniently located to the right of Kilauea's crater. As I watched the eruption under the light of a nearly Full Moon, the magnificent southern star Canopus burned into the bark of that native Ohia tree, then vanished. A minute or so later, Canopus was reborn.

Then I stepped closer to the trunk of the tree, so that it covered a degree of sky, and watched the vanishing act again. The wait seemed eternal. Four long minutes passed before the star finally reappeared.

Suddenly, I realized what this experience had given me: an appreciation for the value of every second of our time.

A matter of life and death

For sensitive souls, I'll admit that when I saw Canopus blink out of view so high in

Stephen J. O'Meara

On the evening of March 18, 2008, stars arched overhead while Stephen J. O'Meara photographed Kilauea Volcano's erupting summit crater, Halemaumau. Canopus is the bright star trail above the tree.

the sky, I felt the sudden loss of beauty, as if the star's flame of life had been extinguished prematurely. This feeling may have ancient roots.

Many cultures looked upon the stars as the souls of their beloved dead. Seeing one disappear from the sky was a time of great anguish; seeing its return brought joy. New Zealand's Maori, for instance, greeted the heliacal rising of Canopus with weeping and lamentations — as if a great voyager had returned safely from a lengthy and dangerous journey.

October's stars have belonged to both the living and the dead. To the Wiccans of old, these stars heralded summer's end — the end of the growing season and of life itself — and the beginning of the Sun's descent into the celestial underworld. Marked by the midnight culmination of the Pleiades star cluster (M45) on October 31, this momentous occasion — known as Samhain (Souw-in) to witches and Halloween to others — rang out the old year and brought in the new. On this mystical evening, the veil separating the living from the dead became transparent, allowing people to spend time with the spirits of the deceased.

Alas, due to precession — the slow, 25,800-year-long wobble of Earth's axis — our perspective of the night sky gradually changes. As a result, the Pleiades no longer rule the south at midnight on Halloween.

Today the cluster culminates at midnight on November 21. In fact, about 3,000 years ago, the Pleiades were at the position of the vernal equinox — the start of spring — and began the astronomical year for the precession cycle. (If precession were the pendulum of our celestial clock, you'd have to wait 71 years for the sky to move 1˚.)

Celestial clocks

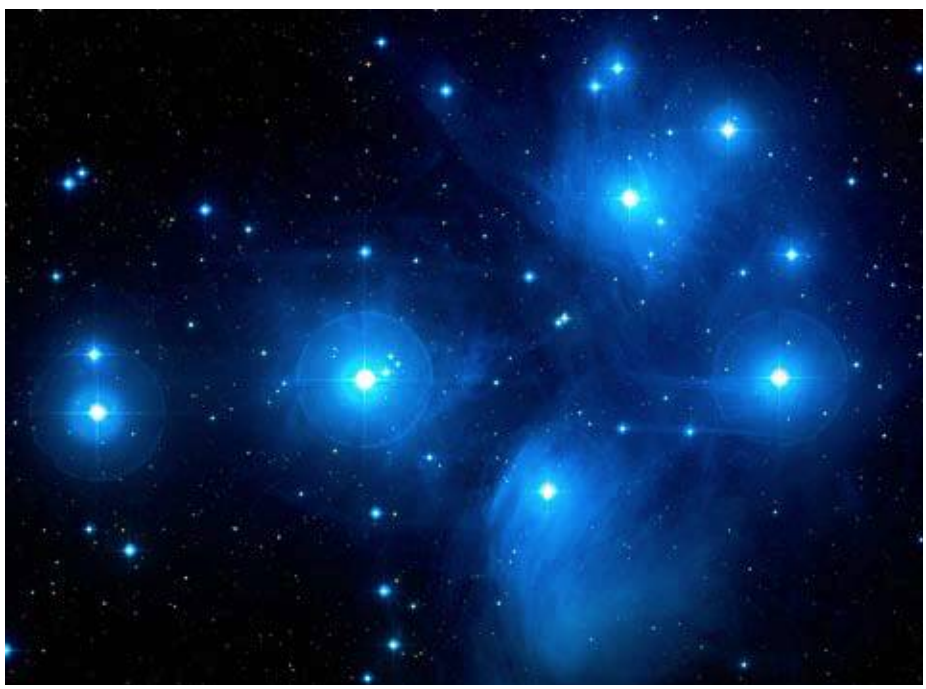
Many peoples throughout history used the Pleiades as their yearly clock. The early Polynesians, for instance, had the Makalii (Pleiades) Year, which began in late November or early December with the first New Moon after the first appearance of the Pleiades in the eastern sky during evening twilight. And every 52 years, the midnight culmination of the Pleiades brought great fear to the ancient Aztecs and Mayans, as they waited for the world to end. If the Pleiades passed the meridian on that momentous and terrifying night, they had another 52 years to live.

The reddish glow of lava in the Halemaumau crater competes with the zodiacal light shining beneath the Pleiades star cluster. The zodiacal light appears to rise from behind the low, rolling mountain in the background, Mauna Loa. The bright white spot in the mountain's silhouette is the Hawaiian Volcano Observatory. Stephen J. O'Meara

From my viewpoint on the lip of the Kilauea caldera last March, I could see the Pleiades low in the west. Although the star cluster had successfully escaped the volcano's fiery plume, it plunged into the dusty "smoke" of the zodiacal light.

To Nebraska's early Pawnee natives, smoke and the Pleiades were intimately united with time. When the Pleiades stood due south at midnight in late autumn — wreathed by the smoke rising from their lodges — the Pawnee prepared for winter. When the cluster shined overhead through the smoke holes at dusk, they started planting. And when the smoke girdled the Pleiades overhead at dawn, it was harvest time.

Whether it's the Pleiades, Canopus, or whatever star you hold dearest, every celestial object is a luminous clock. So go out, wait for one to move, and think about the passage of time. That way, if someone asks you for "just 5 minutes" of your time, you'll know just how long and precious that sacrifice really is.



The sky motion of the Pleiades star cluster (M45), often called the Seven Sisters, marked important life events in many cultures. NASA/ESA/AURA/Caltech

Onward to Pluto NASA's New Horizons spacecraft, launched in 2006, crossed Saturn's orbit June 8, passing another milepost on its voyage to Pluto and the Kuiper Belt.

For the latest news on space discoveries, spacecraft missions, and sky events, visit **Astronomy.com/news**

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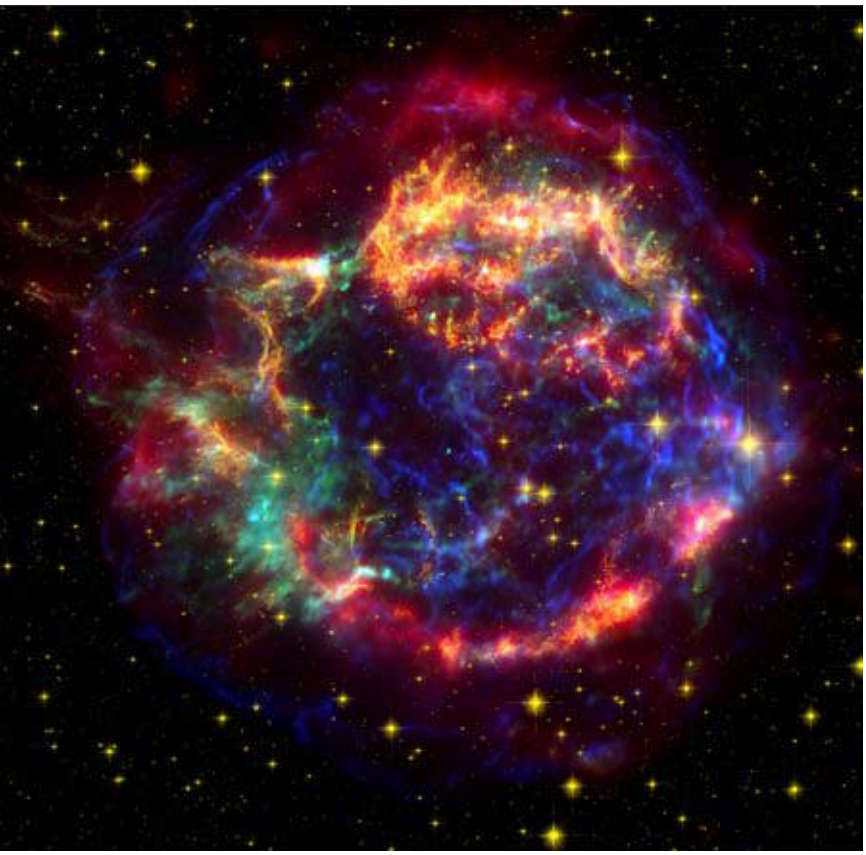

Death star. New research finally reveals the type of star that exploded to form the Cassiopeia A supernova remnant, shown here in a composite of images in infrared, visible, and X-ray wavelengths. NASA/JPL-Caltech/Oliver Krause (Steward Observatory)

Astronomers unearth a star's death secrets

Like forensic scientists sifting through artifacts at an ancient gravesite, astronomers have uncovered new details about a star that exploded 11,300 years ago and created the Cassiopeia A supernova remnant. Observations of light still bouncing around interstellar clouds near the expanding debris cloud provided the key evidence, astronomers reported May 30 in *Science*.

The Cas A remnant is the remains of a red supergiant star, the study reveals. The first light from its explosive demise reached us about 300 years ago. The remnant contains a burned-out sun's dense core (neutron star) surrounded by debris blasted away in the explosion.

Led by Oliver Krause of the Max Planck Institute for Astronomy in Heidelberg, Germany, a team of astronomers zeroed in on faint "light echoes" bouncing off dust grains in the clouds near Cas A. Splitting the light into its component wavelengths (spectrum) allowed scientists to reconstruct the star's pre-supernova chemical composition.

The study suggests the star died in a relatively rare type IIb supernova. This occurs after a massive star loses most of its outer hydrogen gas layer to a companion sun. Previously, scientists did not know what type of supernova created Cas A. — **DANIEL PENDICK**

20 Galactic mistaken identity corrected

22 MESSENGER reveals Mercury's volcanic past

25 Meet the cosmic Cheshire Cat

26 Twin stars show surprising differences

Voyager 2 makes a shocking discovery

Still in the midst of its journey into deep space, the Voyager 2 spacecraft has probed one of the solar system's most distant frontiers. The craft — launched in 1977 with its twin, Voyager 1 — has passed through the solar wind termination shock, where energetic particles cast off by the Sun decelerate abruptly as they encounter interstellar gas.

In 2007, Voyager 2 beamed to Earth the first direct observations of the solar wind termination shock. University of Iowa space physicists Don Gurnett and Bill Kurth reported Voyager's findings July 3 in *Nature*.

The solar wind streams outward at over 1 million mph (1.6 million km/h). At the termination shock, the previously supersonic wind slows to less than the speed of sound — a sudden change.

As the craft passed through this termination shock, an instrument Gurnett designed for Voyager 2 detected an intense burst of turbulence in the solar wind. The turbulence is the space version of a sonic boom.

On August 31, 2007, when Voyager 2 crossed the termination shock, the craft was about 84 times the Earth-Sun distance, or more than twice the average distance between the Sun and Pluto. Voyager 2 is moving at 38,000 mph (61,200 km/h). — **D. P.**

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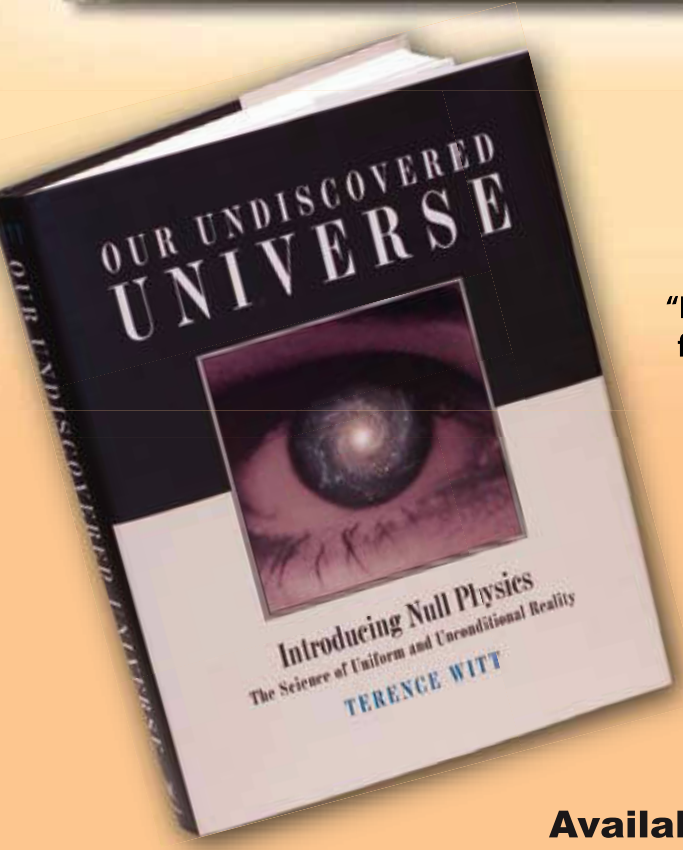

It should be.

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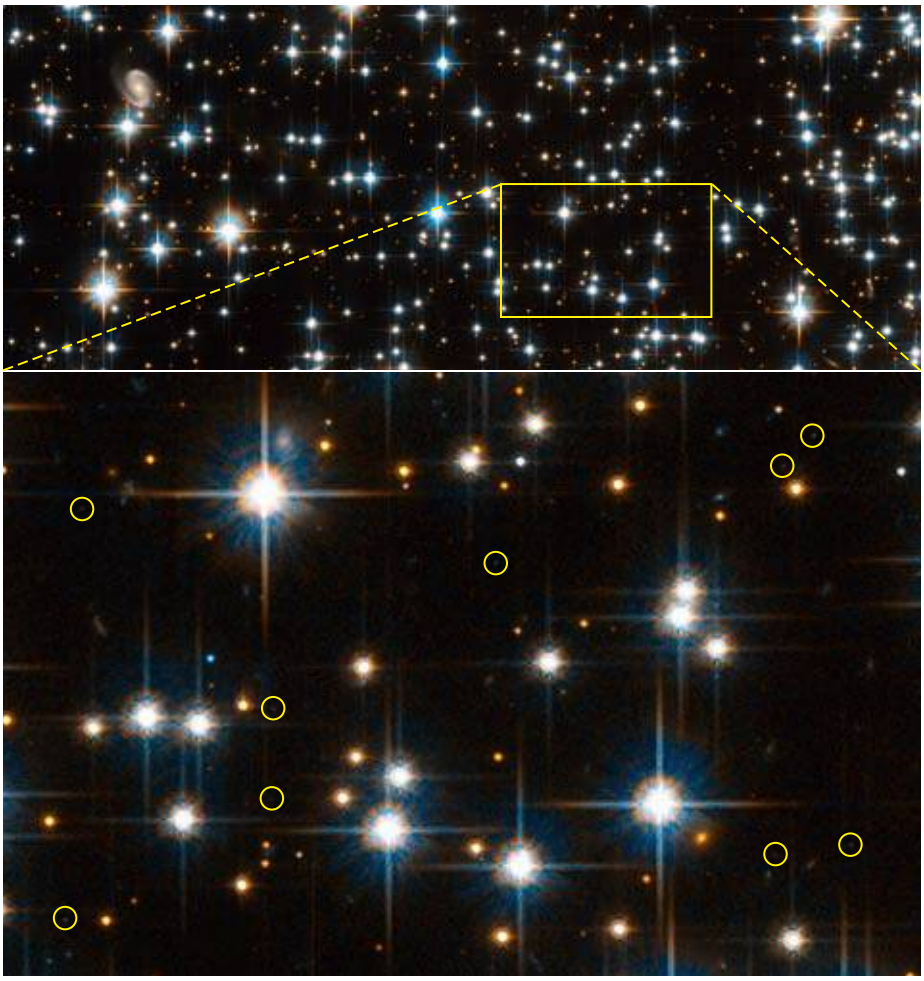
2 more years! In June, NASA's Cassini orbiter completed its planned 4-year exploration of Saturn and its moons and began its 2-year extended mission.



Generation gap. **The Hubble Space Telescope discovered groups of old, burned out white dwarf stars (yellow circles) in the star cluster NGC 6791. Inexplicably, the dwarfs appear to be several billion years younger than neighboring suns at an earlier stage of their evolution.** NASA/ESA/L. Bedin (STScI)

Hubble uncovers white-dwarf age paradox

The star cluster NGC 6791 contains stars with three different ages, a finding that challenges conventional understanding of the evolution of such stellar groupings. The age discrepancy is a problem because stars in an open cluster should be the same age, says astronomer Luigi Bedin of the Space Telescope Science Institute in Baltimore, Maryland.

"They form at the same time within a large cloud of interstellar dust and gas," Bedin says, "so we were really puzzled about what was going on." Bedin and his colleagues reported the paradoxical observations May 10 in *The Astrophysical Journal*.

Using the Hubble Space Telescope, a team of astronomers uncovered three distinct populations of stars in NGC 6791. Two groups are burned-out suns called white dwarfs. Some of the white dwarfs appear to be 6 billion years old — others only 4 billion.

Strangely, normal stars in the cluster — presumably at an earlier, pre-burnout phase of their development — are actually 2 billion years older than the white dwarfs. "This finding means that there is something about white dwarf evolution that we don't understand," says University of Washington astronomer Ivan King, the leader of the Hubble study. — **D. P.**

Galactic mistaken identity corrected

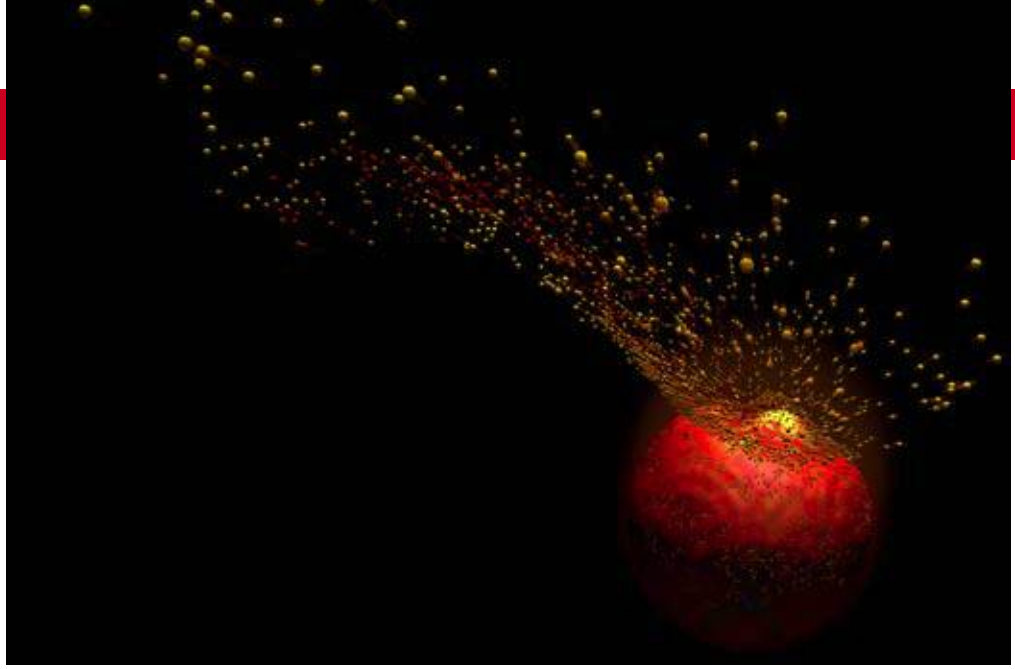
In the 1980s, astronomers categorized a celestial object called G350.1-0.3 as a galaxy. But fresh observations with the European Space Agency's XMM-Newton satellite have revealed G350.1-0.3 as debris from a star that exploded about 1,000 years ago. The findings appeared June 10 in *The Astrophysical Journal Letters*.

Previously, astronomers imaged G350.1-0.3 with a radio telescope, revealing an irregular cloud that did not resemble a typical supernova debris remnant. Astronomers decided it was probably a galaxy.

A team of astronomers led by Bryan Gaensler and Anant Tanna at the University of Sydney, Australia, explored G350.1-0.3 in the X-ray spectrum. They determined the object is not a galaxy, as previously believed. "G350.1-0.3 is indeed the debris of an exploded star, despite its misshapen configuration," Gaensler says. "It turns out to be one of the youngest and brightest supernova remnants in the Milky Way."

Malformed mystery. **This XMM-Newton satellite image, taken in X-ray light, shows the supernova remnant G350.1-0.3 (left) and its neutron-star companion.** ESA/ XMM-Newton/ EPIC (Gaensler et al.)

But why the weird shape? Gaensler and Tanna determined that G350.1-0.3 must have exploded next to a dense cloud of gas, preventing the blast from expanding evenly in all directions. This created the supernova remnant's irregular dimensions. — **D. P.**



S. Lombeyda, M. Marinova, and O. Aharonson (Caltech)

Splat! **This computer-generated image depicts a hypothetical asteroid impact on Mars 3.9 billion years ago.**

New findings help explain two-faced Mars

Three new studies bolster the 20-year-old hypothesis that a massive impact created the stark contrast between Mars' smooth northern plains and its rugged southern highlands. Scientists reported their complementary findings June 26 in *Nature*.

In one study, researchers created a map of the boundary between Mars' north and south hemispheres by removing post-impact volcanic deposits that muddied the picture. The map shows a smooth boundary tracing an oval area — possibly the result of a glancing blow from a huge asteroid.

Two other teams developed computer simulations of the impact, which would have occurred more than 3.9 billion years ago. Producing a two-faced Mars required an impactor 1,200 miles (1,930 kilometers) across striking at an angle of 30° to 60°. The strike would have disturbed half the planet's crust and left behind an oval impact crater about 6,600 miles (10,620 km) long and roughly the same area as Asia, Europe, and Australia combined.

The hypothetical impact scar coincides with a vast lowland sometimes called the Borealis Basin. This lowlying terrain covers 40 percent of the Red Planet's northern hemisphere.

If the scientists are right, the Borealis Basin would be the largest crater known in the solar system. But right now, the evidence for the impact hypothesis remains circumstantial. Actual rock samples from the northern and southern hemispheres — perhaps collected by future human explorers on Mars — could provide the evidence needed to clinch the case. **— D. P.**

Binary pulsar test affirms relativity

Astronomers discovered confirming evidence of Albert Einstein's theory of general relativity by observing a pair of rotating neutron stars, or pulsars. The finding appeared July 4 in *Science*.

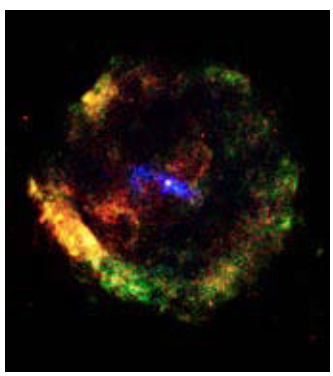
The scientists used the Green Bank Telescope (GBT) in West Virginia to study a binary neutron star system for 4 years. As the neutron stars spin, they emit beams of radio energy.

Astronomers have discovered about 1,700 such "pulsars" to date. The GBT's targets are the first known example of two pulsars orbiting each other.

The pulsars' orbits align such that one of them periodically swings in front of the other, temporarily blocking its signal. The eclipses allowed astronomers to pin down the geometry of the double-pulsar system and track changes in the orientation of one pulsar's spin axis.

Einstein predicted that in a system of two massive objects, such as neutron stars, the gravity and spin of one object should cause the spin axis of the other to wobble. The GBT confirms this for the first time.

So far, general relativity has passed all tests scientists have attempted. The latest double-pulsar study adds new evidence to the pile. **— D. P.**



NASA/McGill/V. Kaspi et al.

Pulsar insights. **This image from the Chandra X-ray Observatory shows a spinning pulsar at the center of a supernova remnant called G11.2-0.3. A rare star system consisting of two such pulsars orbiting each other has provided confirming evidence for Albert Einstein's general theory of relativity.**

QUICK TAKES

SIBERIAN SLAM
One hundred years ago on June 30, a meteorite or comet exploded over the forest near Siberia's Tunguska River, leveling 770 square miles (2,000 square kilometers) of trees.

NEW SPACE MINISTER
Japan appointed Fumio Kishida its first-ever minister of space development. The move is a reaction to fears Japan has fallen behind in promoting space commerce.

ESA WANTS YOU!
The European Space Agency has launched its first recruitment push since 1992 for the European Astronaut Corps.

THE LUNAR LIST
The number of people whose names will ride to the Moon in a microchip on the Lunar Reconnaissance Orbiter has surpassed 1 million.

SHORT TURN
English astronomers observed an asteroid with the shortest rotation rate of any known solar system body: It spins once every 42.67 seconds.

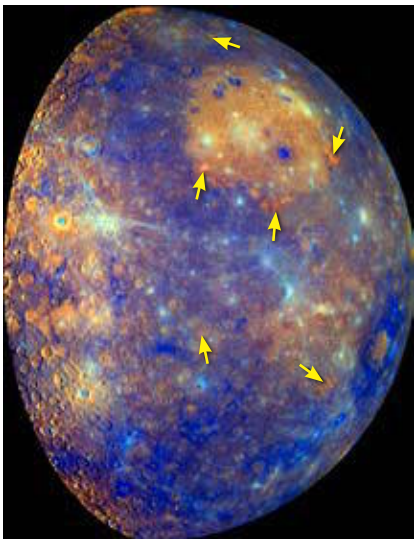
MINERALOGICAL HONOR
The International Mineralogical Association has named a mineral found in comet dust brownleeite in honor of space-dust science pioneer Donald Brownlee.

KAZSAT GOES KAPUT
Kazakhstan's sole telecommunications satellite, the Russian-built KazSat, has died after 2 years in orbit.

BLACK HOLE-LITE
NASA scientists discovered the lowest-mass black hole ever observed. Its mass is only 3.8 times the Sun's, and its diameter measures a mere 15 miles (24 km).

SOHO COMET MILESTONE
The SOHO spacecraft discovered its 1,500th comet in June, making it more successful than all other comet discoverers in history combined.

NASA TESTS THE WIND
Maps based on a decade of data from NASA's QuickSCAT satellite have identified the most promising areas on the ocean to build floating wind-turbine farms.



NASA/JHUAPL/Arizona State University

Volcanic scars. In this MESSENGER view of Mercury, yellow arrows point to surface features formed during volcanic eruptions.

MESSENGER reveals Mercury's volcanic past

The NASA MESSENGER spacecraft's most recent flyby of Mercury shows lava flows, craters, and other unmistakable signs that volcanism has transformed the surface of the solar system's smallest planet. Scientists described the new observations July 4 in one of 11 reports in *Science* devoted to recent MESSENGER observations.

MESSENGER — short for MErcury Surface, Space ENvironment, GEochemistry, and Ranging — last zoomed by the planet in January 2008 (see "Mercury reveals its hidden side," May 2008). The craft will make two more flybys (October 6, 2008, and September 29, 2009) before locking into orbit around Mercury in 2011.

Mark S. Robinson of Arizona State University led a group of 13 scientists that analyzed the composition of Mercury's surface rocks using data collected by MESSENGER's multispectral imaging instrument. "We have now imaged half of the part of Mercury that was never seen by Mariner 10," says Robinson. "The picture is still incomplete, but we'll get the other half on October 6."

In 1974-1975, the Mariner 10 space probe's orbit limited it to imaging less than half the planet's surface. MESSENGER, launched August 3, 2004, is filling in the gaps. **— D. P.**

See the final shuttle fireball

Hot ride. During reentry, an envelope of hot, compressed air (plasma) shrouds the shuttle's leading surfaces, as depicted in this artist's view. From the ground, the craft looks like a flaming meteor. NASA

Astronomy buffs have plenty to be excited about with the Hubble Space Telescope servicing mission — scheduled, as of press time, for an October launch. It will help NASA's orbiting observatory continue to see things the human eye has never detected before.

But the shuttle mission might also present a unique seeing experience of a different kind for skywatchers in the southern United States. It may be the last opportunity in our lifetimes to watch a human spaceship streaking overhead like a fireball — an artificial meteor returning to Earth.

A combination of coincidences makes this rare apparition possible. The shuttle will land in Florida, crossing the continental United States on the way down. Its orbit will result in a nearly straight west-to-east approach to Florida, flying over the southern states. During its descent through the atmosphere, glowing plasma on the craft's leading surfaces will create a brilliant fireball over New Mexico, Texas, and Louisiana.

The shuttle will therefore be potentially visible to millions of people, conditions permitting. The same is not true for landings in California, because the fireball appears over the Pacific Ocean. Nor does it happen after shuttle visits to the International Space Station. The approach to Florida during these landings overflies the more sparsely populated Yucatán Peninsula. Fireball sightings for these missions have been rare.

The most important criterion for seeing a shuttle fireball is a dark sky. Attempts to see fireballs during the day have failed. The lack of suitable seeing conditions alone eliminates 60 percent or so of fireball viewing opportunities.

But the Hubble servicing mission has one important factor in its favor. Flight planning predicts that the continental overflight will occur in the evening, soon after sunset. Once the mission has launched and the actual flight paths to the landing site are calculated, observers will have better clues as to where they must look.

If they are lucky, the shuttle watchers will see a golden-yellow fireball and its persistent milky trail lingering for minutes after the shuttle's passage. From my own experience watching half a dozen such events from my home near Galveston, Texas, I advise you to get yourself somewhere within range. There may never again be a chance to see this.

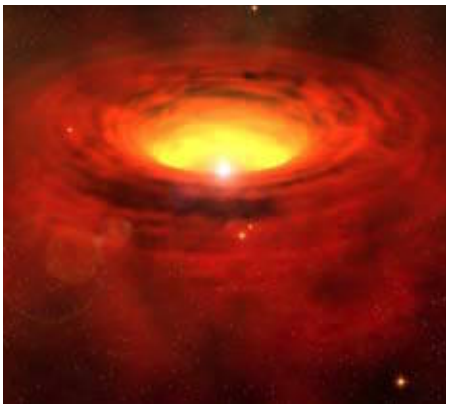
Even at the last moment, there's always the chance the landing will be postponed and follow a different track a thousand miles away from the planned one. And there's always the possibility of bad weather, although my most memorable sighting was of Challenger's fireball passing between lightning-streaked thunderclouds February 11, 1984.

Those were the days I awakened my children in the middle of starry nights to stand under the human-piloted meteorites and then wait expectantly for the dull thud of the sonic boom. Other observers — I never was that lucky — experienced the static-like crackling of "electrophonic sound," a phenomenon long controversial in the history of meteorite studies but thoroughly documented for shuttle fireballs.

The circumstances surrounding the next shuttle fireball will be chancy, no doubt about it. Launch schedule changes may completely eliminate any possibility of witnessing the phenomenon. But if you ever want to see it, start planning — Challenger's landing may well be the chance of a lifetime. **— JAMES OBERG**

Sampling Mars

The international iMars advisory committee has completed its advanced report describing the long-awaited Mars sample return mission. The mission could bring a precious piece of the Red Planet back to Earth in 2023.



Dying giant. In this artist's impression, the supergiant star WOH G64 sheds huge volumes of gas and dust, forming a doughnut-shaped cloud around itself. The inner diameter of the cloud spans 100 times Earth's orbit around the Sun. ESO

Watching a giant die

Astronomers have obtained a detailed look at a dying supergiant sun in the Large Magellanic Cloud, a Milky Way satellite galaxy some 160,000 light-years from Earth. Astronomers led by Keiichi Ohnaka of the Max Planck Institute for Radio Astronomy in Bonn, Germany, published their findings in June in *Astronomy and Astrophysics*.

The star, dubbed WOH G64, is bright, but the dusty environment surrounding it is not as clearly visible. To see it, the astronomers combined two 8.2-meter telescopes into an instrument with an ability to image small details equal to that of a single 60-meter telescope.

The instrument, the European Southern Observatory (ESO) Very Large Telescope Interferometer in Chile, revealed a thick doughnut of dust forming around WOH G64. Even with the world's largest instruments, it is difficult to image dusty doughnuts around aging stars relatively close to Earth, let alone those outside our galaxy.

Based on the new observations, Ohnaka's team concluded that WOH G64 initially packed 25 times the Sun's mass. Since then, it has lost about 10 times the Sun's mass. Despite the dramatic weight loss, WOH G64 would still occupy our solar system out to Saturn's orbit. The diameter of the dust doughnut spans about 1 light-year.

By furiously shedding gas and dust, WOH G64 has slimmed down by 10 to 40 percent of its starting mass. According to Ohnaka and his colleagues, WOH G64's core could collapse as soon as sometime in the next 10,000 years. The resulting supernova explosion would be visible to the naked eye in the Southern Hemisphere. — **D. P.**

Are big-planet systems uncommon?

Sufficient dust to build Jupiter-sized planets exists around fewer than 10 percent of stars in the Orion Nebula (M42), a team of astronomers reported August 10 in *The Astrophysical Journal*. Because the Orion Nebula is a typical star-forming region where suns similar to our own form, the finding suggests that solar systems like ours might be relatively uncommon in the Milky Way Galaxy.

The Orion Nebula is a dense star cluster only a million years old and glowing with the light of newly formed suns. "We think that most stars in the galaxy are formed in dense, Orion-like regions, so this implies that systems like ours may be the exception rather than the rule," says Joshua Eisner of the University of California, Berkeley, the lead author on the report. — **D.P.**

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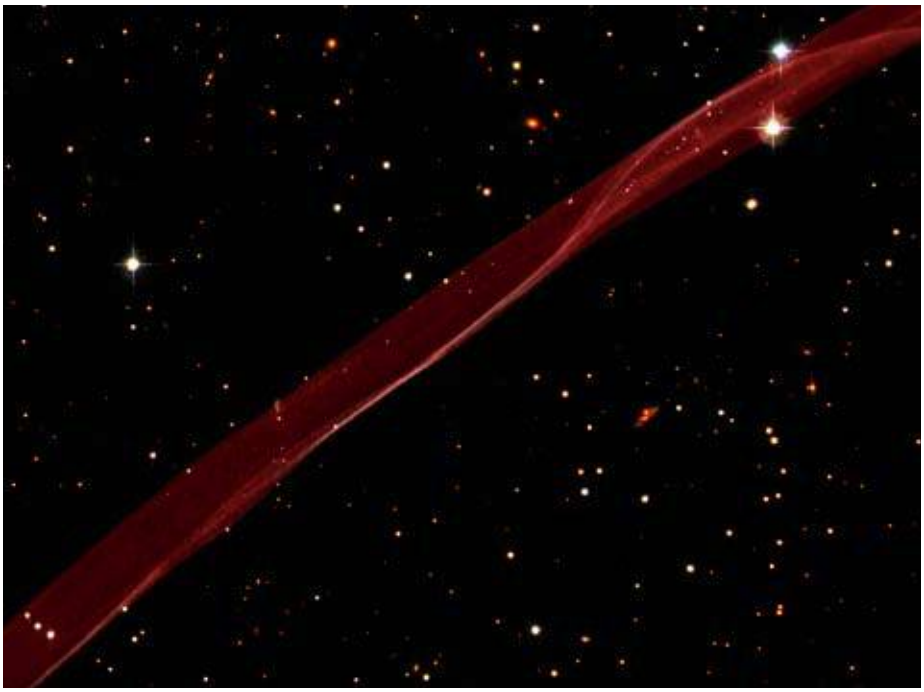


Interstellar ribbon. **The Hubble Space Telescope captured this extreme close-up shot of the expanding edge of a supernova remnant. The star exploded in A.D. 1006 and gleamed in the night sky for more than 2 years.** NASA/ESA/Hubble Heritage Team

Hubble images interstellar ribbon

The Hubble Space Telescope has observed a ribbonlike portion of the expanding blast wave from a star that exploded a millennium ago. In what was possibly the brightest stellar explosion humans have ever glimpsed, the supernova (SN 1006) gleamed in the night sky from Africa to Europe around May 1, 1006.

Using observations taken in 2006 and 2008, Hubble imaging scientists created a color portrait of SN 1006's leading edge. The ribbon's delicate beauty, like a jellyfish's tentacle waving in the dark ocean, belies the violent processes that created it. The ribbon coincides with a portion of the shock wave set in motion when a white dwarf star exploded 7,000 light-years from Earth.

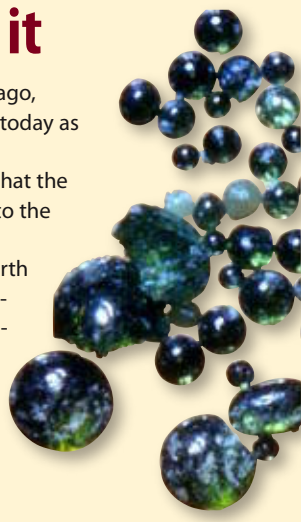
SN 1006 measures about 60 light-years across and continues to expand at a speed of about 6 million mph (9.7 million km/h). The ribbon corresponds to locations where the expanding blast wave from the supernova is sweeping through thin interstellar gas. — **D. P.**

The Moon had water — lots of it

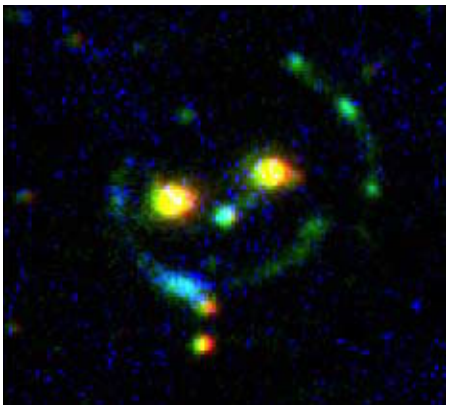
The Moon released a lot of water from its interior more than 3 billion years ago, according to analysis of lunar rock samples. Some of the water may survive today as ice at the Moon's poles, a team of scientists reported July 10 in *Nature*.

The scientists, led by geologist Alberto Saal of Brown University, report that the water originated in the Moon's deep interior. Volcanic eruptions brought it to the surface and released it as water vapor. Most of it leaked into space.

The evidence of lunar water came from glassy beads brought back to Earth during the Moon exploration missions of the 1960s and 1970s. Using a technique called mass ion spectrometry, team member Erik Hauri from the Carnegie Institution for Science measured nearly 10 times the water content the scientists expected to find in the beads. Some of this water may still be on the lunar surface in permanently shadowed polar craters. — **D. P.**



Water glass. **Geologists found traces of ancient lunar water in volcanic glass beads like these, collected by astronauts during the Apollo 15 mission.** NASA



Big smile. **This gravitational lens sytem resembles a grinning cat. Two galaxies mark the cosmic cat's eyes. Arcs of light from more distant galaxies form the cat's smile.** Vasily Belokurov

Meet the cosmic Cheshire Cat

You might call it a happy result: Astronomer Vasily Belokurov at the University of Cambridge in England and his colleagues have discovered a gravitational lens system resembling the ghostly grin of the Cheshire Cat. The team's detailed findings, posted on-line June 26, are expected to appear in the *Monthly Notices of the Royal Astronomical Society*.

Gravitational lenses are rare astronomical alignments that enable a massive foreground galaxy to magnify light from a more distant background object. The Cheshire Cat and similar systems make astronomers smile because they allow observations of distant galaxies early in their evolution.

The Cheshire Cat system consists of several elements. A pair of massive galaxies forms the cat's eyes. Like giant lenses, their gravity bends and distorts light from other, more distant galaxies into arcs. One arc forms the cosmic cat's grin; two others bracket the imaginary cat's head. The arcs originate from at least two different background sources, and maybe more.

The cat represents a wide and powerful gravitational lens. "These objects give us the chance to study the most massive galaxies in the universe," Belokurov says. "These are unique laboratories to study dark matter."

Such large gravitational lens systems, with amplifications of 20 to 40 times, allow astronomers to measure the halos of "dark matter" around distant galaxies. Dark matter emits no light, rendering it invisible to conventional optical telescopes. But dark matter does have gravity, so it can be detected and measured using a gravitational lens system. — **D. P.**

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Bad vibes An internal NASA report released July 16 described glitches in the new Ares launcher, scheduled to replace the space shuttle by 2015. Problems include dangerous shaking at liftoff.

Orion Nebula: NASA/JPL/HST; Inset: David James

Mismatched twins. The arrow (inset image) points to curiously mismatched "twin" stars in the Orion Nebula (M42), a stellar nursery about 1,500 light-years from Earth. The pair orbit so close to each other, they form a single point even in this highly magnified telescopic image.

Twin stars show surprising differences

The stars in a binary star system in the Orion Nebula show important differences, despite having the same mass. This challenges some assumptions about such star pairings. A team headed by Keivan Stassun of Vanderbilt University and Robert D. Mathieu from the University of Wisconsin-Madison published its findings June 19 in *Nature*.

"There are lots of examples of binary systems whose component stars are different, but that's always because the two stars have different masses, and thus all of their other properties are different also," Stassun says. "In this case, the two stars have the same mass and thus should be identical in every respect."

But they are not the same. The astronomers gathered information about the binary system from 15 years of observations collected by different telescopes. They determined that one member of the binary system is 2 times brighter than the other, with a surface temperature of about 570° Fahrenheit (300° Celsius) higher. A successful theory should be able to account for such less-than-identical twins.

The Orion Nebula, a mass of dust and gas 1,500 light-years from Earth, is a famous stellar nursery. The mismatched stars in the binary system are only a million years old, which is equivalent to infancy in a human lifespan. — **D. P.**

New greenhouse solution keeps early Earth warm

How did early Earth's atmosphere stay warm enough to keep the oceans from freezing at a time when the Sun was 25 percent dimmer than today? The secret ingredient, says a team of German researchers, is having enough carbon dioxide to trap heat in the atmosphere.

Carbon dioxide (CO_2) warms the atmosphere due to the "greenhouse effect." Not surprisingly, past attempts to solve the "faint young Sun problem" depended on CO_2 to keep Earth's atmosphere relatively balmy. But this appeared to require a large concentration of CO_2, for which there is no evidence in the geological record.

Now, Philip von Paris of the German Aerospace Centre in Berlin and colleagues have developed a new computer model that restores CO_2 as the answer to the faint young Sun dilemma. "Our results imply the amount of CO_2 needed to warm the surface of early Earth might have been overestimated by previous studies," von Paris and his fellow researchers wrote in July's *Planetary and Space Science*.

The model suggests a concentration of CO_2 less than 10 percent of the previously estimated amount, along with other factors, could keep Earth's climate warm enough to maintain liquid seas. — **D. P.**

BRIEFCASE

New ocean eye in orbit

On June 20, Vandenberg Air Force Base (California) launched a new Earth-observing satellite, Jason-2. The 1,100-pound (500 kilograms) craft will gather data on the topography of the ocean surface. The information is essential to studies of global climate change and hurricanes. — D. P.

Entire Moon is within reach

A detailed NASA review completed in June concluded that the post-shuttle Ares V cargo lifter and Altair lunar lander will be able to ferry astronauts and equipment to any location on the Moon. NASA expects the Ares crew launcher will be ready for launch by 2015. — D. P.

Shuttle legacy

Physicists proved that stirring liquid xenon gas makes the fluid thinner — using data recovered from a mangled hard drive found in the wreckage of the Space Shuttle Columbia. The craft burned up on reentry in 2003, killing all seven astronauts onboard. Some of the xenon experiment data was still on the ship. — D. P.

25 years ago in *Astronomy*

October 1983

Paul Patton's "Daedalus: Design for a starship" appeared in the October 1983 issue of *Astronomy* and discussed a hypothetical craft to carry people to other stars. From 1973 to 1978, scientists from the British Interplanetary Society conducted a study to design a spacecraft capable of interstellar travel. This study, known as Project Daedalus, concluded that a robot starship could be ready — hypothetically — to explore other star systems by the middle of the 21st century.

Actually building such a ship was not in the plan, however. As Patton explained, "The Dadedalus study . . . sought to show that interstellar flight can be discussed in sensible terms within the framework of established science and technology."

October 1998

10 years ago in *Astronomy*

The October 1998 issue of *Astronomy* featured an article on galaxy hunter Charles Steidel. "Outsmarting the early universe," by Marcia Bartusiak, discussed the astronomer and how he studied the distant universe. At the time the article was printed, Steidel and his colleagues had identified more than 600 distant galaxies, with 1,500 more candidates awaiting final confirmation.

Even though there are still many questions about galaxies that need to be answered, Steidel's research may someday help astronomers discover how many distant galaxies there are, how they are clustered, and when they formed. — **MEGAN MCCHAIN**

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How we'll fix Hubble

NASA returns to the Hubble Space Telescope one last time. **by Richard Talcott**

Astronauts clear the way for the Advanced Camera for Surveys by removing the Faint Object Camera during Servicing Mission 3B. NASA

When shuttle astronauts last left the Hubble Space Telescope in March 2002,

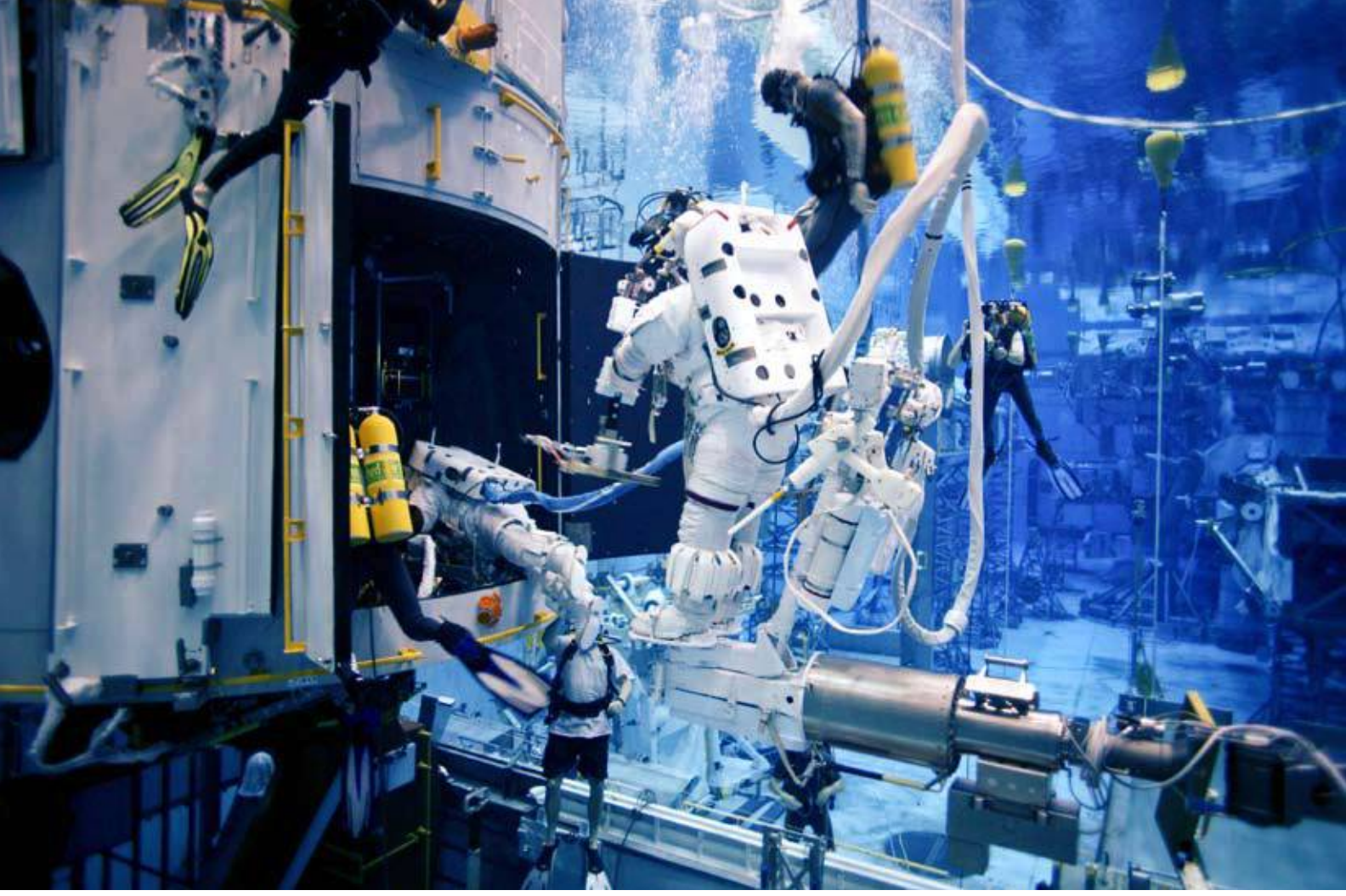
NASA's venerable observatory was looking spiffy. The new Advanced Camera for Surveys (ACS) promised twice the resolution, twice the field of view, and 5 times the sensitivity of Hubble's previous workhorse, the Wide Field and Planetary Camera 2. And the Near Infrared Camera and Multi-Object Spectrograph (NICMOS) roared back to life with an experimental cooling system to keep its detectors cold.

To top it off, new solar arrays delivered 30 percent more power to the telescope and doubled the amount available to the science instruments. Even though NASA launched Hubble in 1990 and designed it several years before then, Servicing Mission 3B brought the observatory into the 21st century.

The telescope more than met the heightened expectations. The ACS returned stunning images of the cosmos that captured the hearts and minds of scientists and the public alike. Top on the list: the incredible Hubble Ultra Deep Field, which revealed galaxies forming within a billion years of the Big Bang.

Richard Talcott *is a senior editor of* Astronomy.

Astronauts installed new solar arrays on Hubble during Servicing Mission 3B in March 2002. Hubble basks in the glow of sunrise, while Earth's atmosphere shines brightly in the background. NASA



Astronauts mingle with divers in the Neutral Buoyancy Lab at NASA's Johnson Space Center in Houston. In the lab, which holds 6.2 million gallons of water, astronauts practice techniques and test tools on a Hubble mock-up. NASA

But time has not been kind to Hubble. The ACS suffered a serious power failure in January 2007. Of its three observing channels — wide-field, high-resolution, and solar-blind — only the last still functions. (And it's not the one that takes those breathtaking images.)

A power-supply failure also doomed the Space Telescope Imaging Spectrograph (STIS) in August 2004. This instrument made several of Hubble's most exciting discoveries, among them analyzing the constituents of an exoplanet's atmosphere and weighing supermassive black holes in galaxy cores.

To make matters worse, a fifth servicing mission, originally scheduled for 2004, had to be postponed after the Columbia tragedy. NASA later canceled the mission over safety concerns. It wasn't a popular decision. Following the shuttle's successful return to flight and a closer look at the safety issue, NASA reversed course.

Heading back to Hubble

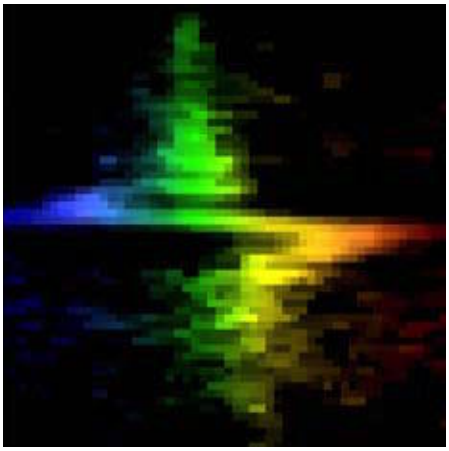
If all goes according to plan, space shuttle Atlantis will lift off October 8 on an 11-day mission to repair and upgrade Hubble. Astronauts on Servicing Mission 4 (the numbers seem out of whack because NASA broke the third servicing mission into two parts) have ambitious plans.

They will install two new instruments: Wide Field Camera 3 (WFC3) and the Cosmic Origins Spectrograph (COS). They will attempt repairs to the ACS and STIS. And they will extend Hubble's operational life by at least 5 years by replacing gyroscopes, installing new batteries, and adding thermal insulation.

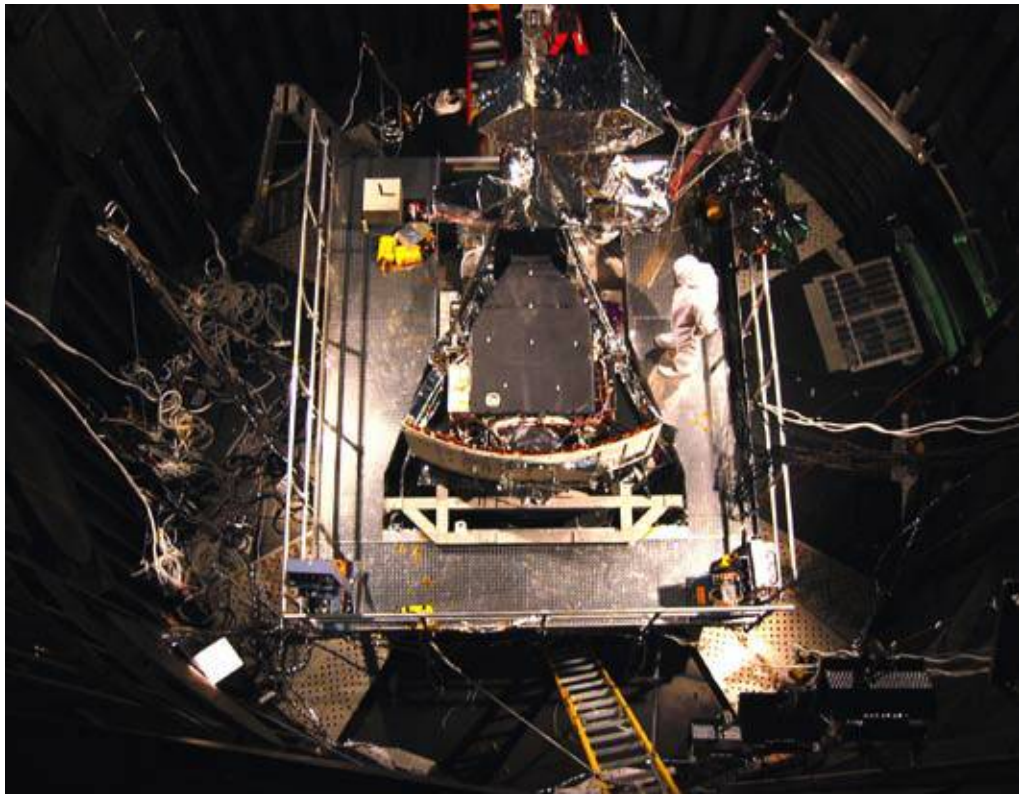
The biggest excitement revolves around the two new instruments. WFC3 takes advantage of advanced technology to see deeper into the universe. But its ability to simultaneously observe at ultraviolet, visible, and near-infrared wavelengths makes WFC3 unique. This capability will allow it to observe a galaxy and see hot young stars (which radiate mostly in the ultraviolet) and cool old stars (which glow chiefly in the red and near-infrared) at the same time.

In the ultraviolet, WFC3's wide field of view (160 arcseconds on a side) and heightened sensitivity combine to give it 35 times more discovery power than the ACS' high-resolution channel — the previous best ultraviolet instrument. Likewise, WFC3 will outperform NICMOS by a factor of 15 in the near infrared. Still, the Advanced Camera for Surveys wins a showdown with WFC3 at visible-light wavelengths, so Hubble scientists hope the ACS repairs work.

Researchers will use WFC3 to study galaxy evolution across the universe. By the time high-energy radiation emitted by distant galaxies reaches Earth, cosmic expansion shifts the light to red and near-infrared wavelengths. With WFC3's wide wavelength coverage, it can compare these distant galaxies with ultraviolet-emitting galaxies closer to home. Working with the ACS, WFC3 will also study dark matter and dark energy with a



A spectrum of M84 — a giant elliptical galaxy in the Virgo cluster — shows a supermassive black hole at the galaxy's center. The Space Telescope Imaging Spectrograph (which astronauts plan to repair) found gas swirling at 880,000 mph (1.44 million km/h) near the galaxy's core. Blue shows rapid motion toward us, while red indicates motion away. NASA/Gary Bower/Richard Green (NOAO)/STIS Instrument Definition Team



The Wide Field Camera 3 sits in the Space Environment Simulator at NASA's Goddard Space Flight Center. This chamber simulates the extreme conditions the camera will face in space. NASA

sensitivity twice what Hubble achieved before. WFC3 will take the place of Wide Field and Planetary Camera 2, which the astronauts will return to Earth.

The Cosmic Origins Spectrograph will devote most of its time to studying the large-scale structure of the universe and learning how galaxies, stars, and planets form and evolve. A spectrograph breaks down incoming light into its constituent colors, revealing an object's temperature, density, composition, and velocity. COS operates at ultraviolet wavelengths. It will detect objects 30 times fainter than STIS could muster at the shortest wavelengths, and twice as faint as STIS managed at longer wavelengths.

Although COS will have many tasks, its most important will be to study the structure and composition of the "cosmic web" — the long, narrow filaments of galaxies and gas where most of the universe's mass resides. It will do this by observing distant quasars, whose light passes through the web on its way to Earth. The web material absorbs some of the light and imparts its spectral fingerprint in the process.

COS will slide into the slot now used by the Corrective Optics Space Telescope Axial Replacement (COSTAR), the "spectacles" NASA installed in 1993 to fix Hubble's blurry vision. Because all current instruments have their own internal corrective optics, COSTAR is no longer needed.

Tricky repairs

No one expects major problems putting in the new instruments, but fixing the old ones could be a different story. Neither ACS nor STIS was designed to be fixed in orbit, and the task ahead could be tedious. Take STIS, for example. The plan is to replace a low-voltage power supply board. But accessing the board requires removing 111 screws.

No one wants 111 screws floating in zero-g, where they could drift away or perhaps get loose inside and damage the telescope. So, NASA engineers designed a clear "capture plate" that fits over the access panel. The plate will capture all the screws and any metal debris as the astronauts painstakingly remove them with a special low-torque screwdriver. Once they remove the panel, the astronauts will replace the failed power supply board with a new one, in much the same way you'd replace a computer circuit board. Fortunately, the new access panel attaches with two levers, so the astronauts won't have to screw in 111 fasteners.

Checklist for Servicing Mission 4

Four spacewalking Atlantis astronauts will break into two-person teams to work on Hubble. The astronauts will make a total of five spacewalks, each scheduled for 6 to 7 hours. Although things could change depending on mission progress, this is the current plan.

- ☑ **Spacewalk 1:** Install the Wide Field Camera 3; replace the first set of three batteries; attach the Soft Capture Mechanism
- ☑ **Spacewalk 2:** Install six new gyroscopes; replace the second set of three batteries
- ☑ **Spacewalk 3:** Install the Cosmic Origins Spectrograph; part 1 of Advanced Camera for Surveys repair
- ☑ **Spacewalk 4:** Repair the Space Telescope Imaging Spectrograph; install new thermal blankets
- ☑ **Spacewalk 5:** Replace a Fine Guidance Sensor; complete Advanced Camera for Surveys repair

Cold hydrogen gas laced with dust marks the site of new star formation in the Carina Nebula. Hubble's Advanced Camera for Surveys, which took this image, failed in 2007. Shuttle astronauts hope to repair it on this servicing mission. NASA/ESA/N. Smith (University of California, Berkeley)/Hubble Heritage team (STScI/AURA)

Fixing the ACS should consume approximately the same amount of time. In this case, the astronauts will replace the CCD electronics box in the wide-field channel, then power it with a new low-voltage power supply. NASA expects these two repairs to take between 3 and 4 hours each. Installing the WFC3 and COS should be only 2- to 3-hour tasks.

Hubble's instruments may receive most of the glory, but they're only part of what keeps it operating. Servicing Mission 4 will make sure Hubble can perform through the end of its mission.

Hubble wouldn't be worth much if astronomers couldn't point it precisely and keep it on target while it orbits Earth once every 97 minutes. Hubble must keep its pointing stability to within 0.007 arcsecond — equivalent to locking a laser beam on a dime from 200 miles away.

Gyroscopes and Fine Guidance Sensors work together to keep Hubble pointing accurately. Hubble has six gyroscopes, but they degrade over time. At the start of the mission, three were needed to point the spacecraft (the other three were

A Hubble history

Astronauts and Hubble go together like peanut butter and jelly. Servicing Mission 4 marks the fifth time astronauts have gone back to Hubble since the shuttle Discovery deployed the space telescope in April 1990. Here are the main tasks astronauts accomplished that affected science instruments.

Servicing Mission 1 (December 1993): Endeavour astronauts installed the Wide Field and Planetary Camera 2 and the Corrective Optics Space Telescope Axial Replacement. The latter instrument corrected Hubble's fuzzy vision, created by an incorrectly shaped primary mirror.

Servicing Mission 2 (February 1997): Discovery astronauts installed the Near Infrared Camera and Multi-Object Spectrograph and the Space Telescope Imaging Spectrograph.

Servicing Mission 3A (December 1999): NASA split Servicing Mission 3 into two parts. This Discovery mission was pushed up to perform needed maintenance (installing new gyroscopes was the key). No science instruments changed.

Servicing Mission 3B (March 2002): Columbia astronauts installed the Advanced Camera for Surveys and a new cooling system for the Near Infrared Camera and Multi-Object Spectrograph.

The Hubble Space Telescope was photographed from the space shuttle Discovery following Servicing Mission 2 in February 1997. Shuttle astronauts should make their final trip to Hubble in October. NASA

spares). Three gyros have already failed. Engineers found a way to point Hubble with only two, and they began operating the telescope this way in 2005. The Atlantis astronauts will replace all six gyros.

The telescope has three Fine Guidance Sensors and needs two. (The third serves as a backup. Because the sensors can measure angles precisely, the backup also serves as a science instrument.) Astronauts will swap out one of two sensors showing signs of ill health.

The crew members will perform two other maintenance tasks. First, they will replace the six batteries that provide power when Hubble flies through Earth's shadow. (Night lasts 36 minutes each orbit.) The six batteries, all original equipment, have survived more than 13 years beyond design expectations. The astronauts also will install some new thermal blankets. They protect the telescope's insulation from the severe and rapid temperature changes that take place as the observatory orbits from hot Sun to frigid night and back again.

Astronaut Jeffrey Hoffmann removes the Wide Field and Planetary Camera 1 during Servicing Mission 1 in December 1993. The Wide Field and Planetary Camera 2, with corrective optics, took its place. NASA

Atlantis will carry a crew of seven. Scott Altman will command the mission and Gregory Johnson will pilot the shuttle. Megan McArthur will operate the shuttle's robotic arm. And Andrew Fuestel, Michael Good, John Grunsfeld, and Michael Massimino will perform the spacewalks, in teams of two. Both Altman and Massimino are making their second trip to Hubble, while Grunsfeld is on his third servicing mission.

Farewell to Hubble

NASA plans to keep Hubble operating at least through 2013, when the observatory's successor, the James Webb Space Telescope, should begin operations. In order to keep the craft operating until then, Atlantis will boost Hubble to a higher orbit after the service.

To de-orbit the spacecraft safely, NASA needs to make Hubble accessible to a next-generation space vehicle. (NASA plans to retire the shuttles in 2010.) That's why Atlantis astronauts will attach the Soft Capture Mechanism to Hubble's back end. This will allow a next-generation vehicle to capture and direct the spacecraft to a controlled reentry.

But this fate remains years away. Until then, expect Hubble to continue pushing the boundaries of scientific knowledge. The first new results and images should come within a month or so after Atlantis leaves Hubble. We're looking forward to publishing many of them.

Saturn revolution

In its first 4 years at Saturn, NASA's Cassini spacecraft has discovered methane lakes on Titan, icy plumes on Enceladus, and unimagined details in the planet's rings and atmosphere. **by Linda Spilker**

Four years after the Cassini spacecraft entered Saturn orbit, the mission's findings continue to enthrall scientists. From continuing images of the solar system's loveliest rings, to following the progress of titanic storms, to a first-ever landing on a planet-sized moon, there's no doubt Cassini has delivered on its scientific promise.

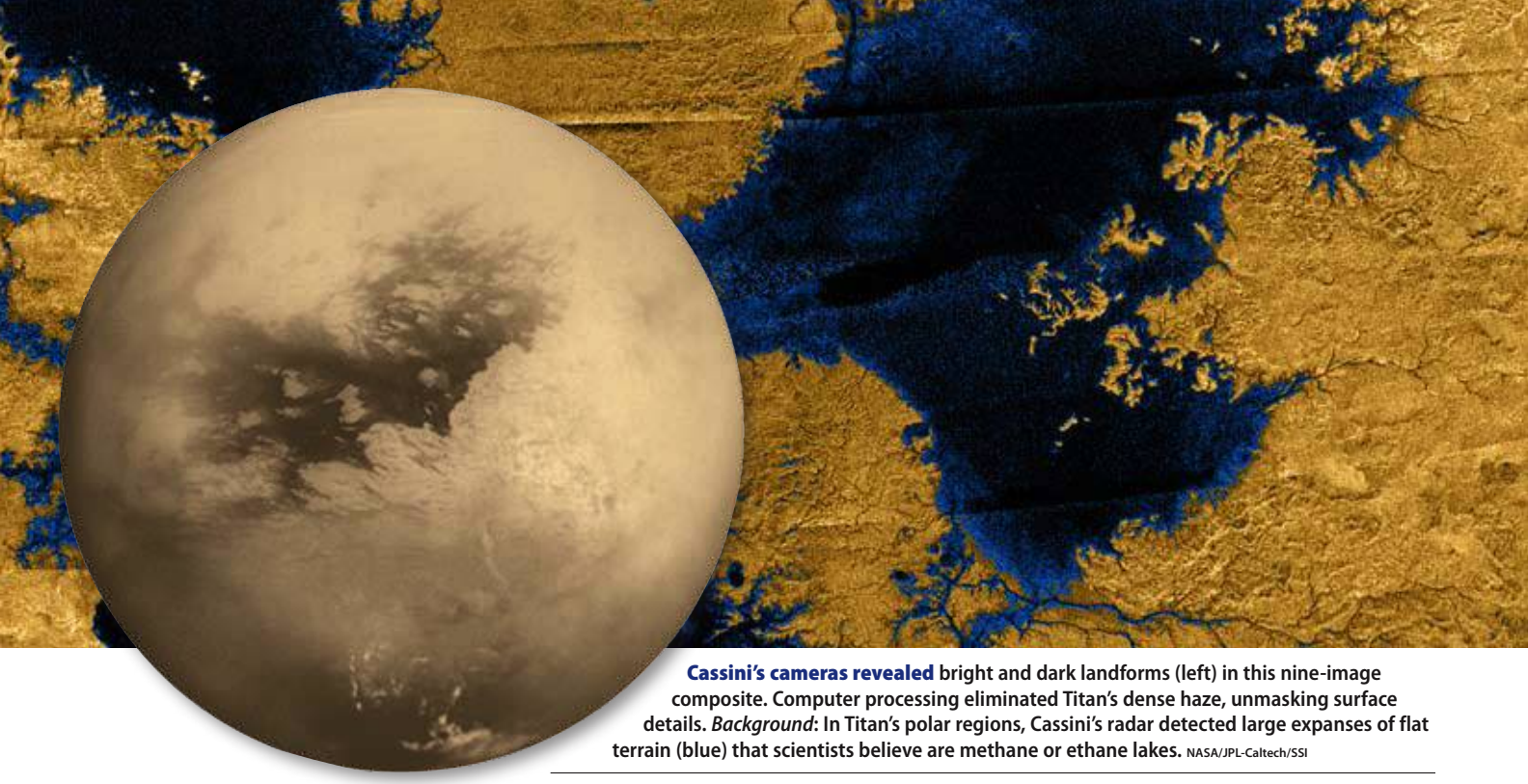
NASA agrees. With the probe's primary mission complete, the agency is funding another 2 years of exploration. Dubbed the Cassini Equinox Mission, this extension includes Saturn's August 2009 equinox, when the Sun will cross Saturn's ring plane and illuminate its opposite side. The equinox also represents a chance to monitor the planet and its biggest moon, Titan, for seasonal changes.

Cassini is the largest interplanetary spacecraft ever built and is one of the most ambitious missions ever flown. Scientists and engineers from NASA, the European Space Agency (ESA), and the Italian Space Agency spent more than a decade building the 22-foot-tall (6.7 meters), 13-foot-wide (4m) spacecraft. Cassini used gravitational assists from close flybys of Venus, Earth, and Jupiter to reach its distant target.

After a marathon 7-year, 2-billion-mile (3.5 billion kilometers) journey, the Cassini orbiter and the Huygens probe blazed into Saturn orbit June 30, 2004. From then to June 30, 2008, when the prime mission ended, Cassini orbited Saturn 76 times, completed 45 flybys of Titan, and made close swings past seven other moons: Enceladus, Tethys, Dione, Rhea, Hyperion, Iapetus, and Phoebe.

A much-anticipated mission highlight, the Huygens probe's exploration of Titan, came just months after Cassini arrived. Titan is Saturn's largest moon — and the second largest in

Cassini now travels in orbits that take it far from Saturn's ring plane. These high angles provide stunning views, such as this mosaic made from images taken May 9, 2007. The backlit rings appear dark from this vantage point, some 700,000 miles (1.1 million kilometers) from the planet. The image reveals details as small as 39 miles (62 km) in diameter. NASA/JPL-Caltech/SSI



Cassini's cameras revealed bright and dark landforms (left) in this nine-image composite. Computer processing eliminated Titan's dense haze, unmasking surface details. *Background*: In Titan's polar regions, Cassini's radar detected large expanses of flat terrain (blue) that scientists believe are methane or ethane lakes. NASA/JPL-Caltech/SSI

the solar system, after Jupiter's Ganymede. It hosts a dense nitrogen- and methane-rich atmosphere that many scientists think resembles Earth's original atmosphere before life appeared some 4 billion years ago. Ultraviolet sunlight breaks apart methane molecules, and these molecular pieces recombine to form more complex substances, including ethane, propane, acetylene, and benzene. This natural smog makes Titan's surface difficult to see. Before Cassini and Huygens, no one knew exactly what to expect.

Ice station Huygens

On January 14, 2005, the ESA's Huygens probe became the first to land on Titan. After separating from Cassini 20 days earlier, Huygens cruised toward the moon at 12,300 mph (19,800 km/h). As the dense atmosphere swallowed the probe, Huygens slowed to 900 mph (1,400 km/h) in just 3 minutes.

After deploying a parachute, the probe measured wind speeds, temperatures, and pressures, analyzed the composition of Titan's atmosphere, and took pictures. Huygens measured pressures and temperatures all the way to the surface, and it sampled the atmosphere's composition at several heights. These measurements confirmed nitrogen and methane as the main constituents and showed that the methane concentration rose steadily from 1.5 percent in the upper atmosphere to 5 percent at the surface.

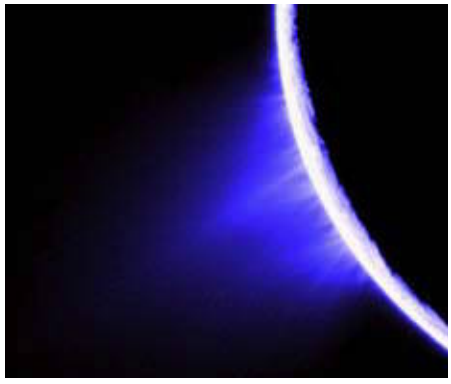
Huygens descended for 2 hours, 27 minutes. The probe detected methane clouds about 16 miles (26 kilometers) up and sensed a methane or ethane fog near the surface. Huygens then touched down, recording a temperature of –292° Fahrenheit (–180° Celsius) at its landing site. Despite the frigid cold, Huygens transmitted data for more than an hour.

As the probe floated through Titan's haze-choked atmosphere, its cameras sent back 375 images of a poignantly earthlike surface, complete with rolling hills, drainage channels leading to a possible shoreline, erosion features, and "rocks" made of ice. Scientists believe that the same physical processes shaping such features on Earth — mainly, erosion from wind and flowing liquids — also shape them on Titan.

There, liquid methane plays the same role water plays on Earth. Methane condenses, forms clouds, and rains onto the surface, where it creates rivers and streams that carve channels. If the methane isn't continually replenished from some source — perhaps volcanic activity — the atmosphere would run out of it.

One of Titan's biggest surprises was the absence of global methane and ethane oceans. Scientists originally

Linda Spilker *is the deputy project scientist for the Cassini mission, which she has participated in since 1988.*



Cassini imaged and flew through Enceladus' icy jets (above). The jets erupt along "tiger stripes," fissures coated with fresh ice that arc over the moon's south pole. The tiger stripes appear blue in the view at left. NASA/JPL-Caltech/SSI

thought liquid methane and ethane would accumulate on the surface and form large lakes and even oceans. Instead, Cassini's radar instrument penetrated the smoggy sky and provided detailed global views of flow features, dry lake beds, craters, possible volcanoes, dune fields, and other terrain.

As the probe's radar scanned Titan's north polar region, though, it revealed large regions of flat terrain that scientists now interpret as lakes and seas. Just a sprinkling of lakes occurs around the warmer southern pole, which suggests the lakes experience a seasonal cycle. Cassini will be watching for changes.

Enceladus gushes

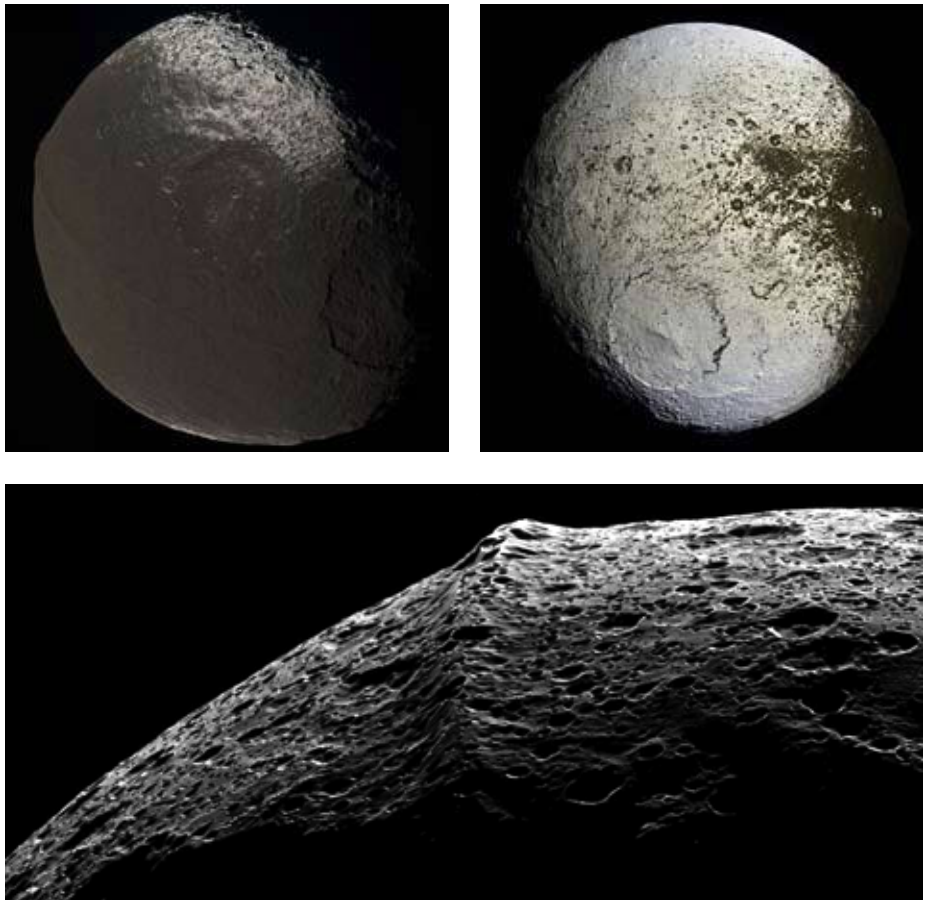
Another amazing discovery was that of erupting geysers at the south pole of the 310-mile-wide (500 km) moon Enceladus. The particles from these icy plumes orbit Saturn to form its E ring.

The first hint that something unusual was going on came from magnetic-field measurements Cassini made during a flyby in 2005. Images revealed at least eight individual jets, which point back to their source locations.

The jets arise from long linear fractures — "tiger stripes" — that arc over the moon's south pole. Cassini showed that the fractures' walls contain fresh ice crystals and organic molecules, and thermal maps uncovered hot ribbons running the length of each tiger stripe. These fractures were much warmer than they should be if heated by sunlight alone.

Scientists are still searching for the mechanism that powers Enceladus' geysers. Without some additional energy source, this small moon should be frozen solid. Friction from tidal flexing is one possibility; this is what fuels volcanic activity on Jupiter's moon Io. But scientists don't believe there's enough tidal flexing in Enceladus' current orbit to drive the geysers.

On March 12, 2008, Cassini flew within 30 miles (50 km) of Enceladus and swept through water vapor and ice particles lofted by the geysers. The craft's ion and neutral mass spectrometer measured the composition of individual jets and discovered organic chemicals of the sort associated with comets. With this, Enceladus makes the short list of promising sites to search for life in the solar system.



Iapetus is a two-faced moon. **It hosts a dark hemisphere (top left) that leads the moon's orbit around Saturn, and a bright hemisphere (top right) that trails. Water vapor from the dark side migrates to the opposite hemisphere, where it freezes out as a fresh icy coat. *Bottom*: A 12-mile-high (20 km) ridge that extends halfway around the moon gives it a walnutlike appearance.** NASA/JPL-Caltech/SSI

Stay tuned. During the Cassini Equinox Mission, the spacecraft will complete additional Enceladus flybys.

More weird moons

Cassini found a broad disk of debris and a probable ring around Rhea, Saturn's second largest moon, during a close flyby in November 2005. The debris disk might be a remnant from a past asteroid or comet collision. Rhea may be the first moon in the solar system to sport a ring; scientists will continue to study it during Cassini's Equinox Mission.

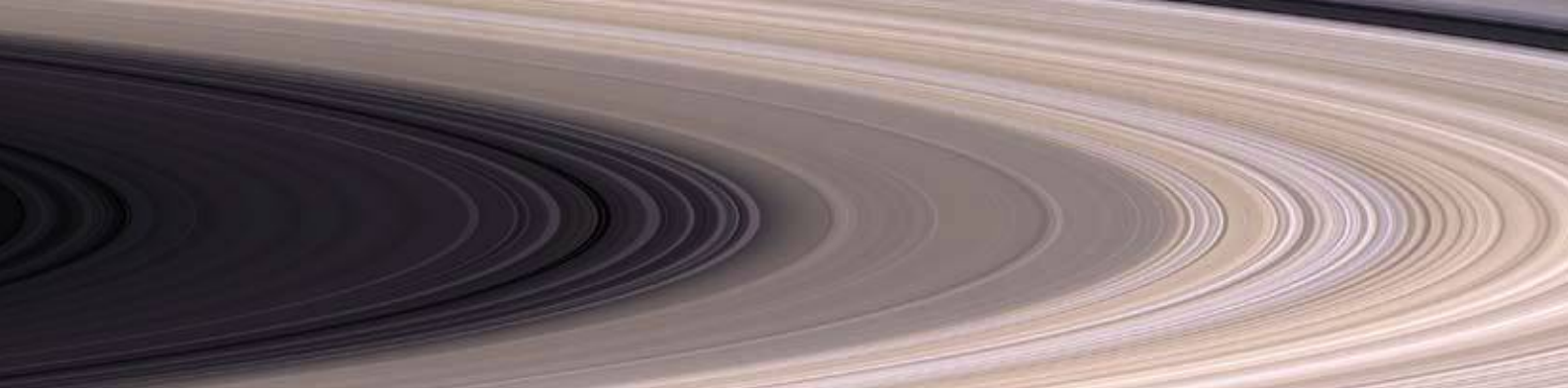
Iapetus is a two-faced moon with one side as white as snow and the other as dark as charcoal. The side of Iapetus that faces forward as it orbits Saturn is the moon's darker half.

Scientists think a thermal segregation model may explain Iapetus' two-toned appearance. Infrared observations indicated that the dark material is warm enough (–231° F [–146° C]) to release small amounts of water vapor. This then migrates to the bright, colder regions, such as the moon's poles or bright hemisphere, and condenses.

The dark material loses its surface ice and gets darker; the bright regions accumulate ice and get brighter. Images also showed tiny craters punching through the dark material, revealing bright ice underneath. This indicates that the dark material is generally thin.

Cassini also discovered an equatorial mountain range on Iapetus that circles large portions of its equator. This ridge reaches 12 miles (20 km) high — twice the height of Mount Everest — in some places. This curious formation gives Iapetus the appearance of a walnut. No other moon in the solar system has such a prominent geological feature.

To date, Cassini has discovered five new moons, including tiny Daphnis, orbiting inside the A ring in the Keeler gap. Methone and Pallene orbit between Mimas and Enceladus. Then there's Polydeuces, an object gravitationally captured



Saturn's rings reveal their incredible beauty and complexity under Cassini's gaze. This view, a six-image mosaic, encompasses 39,000 miles (62,000 km), from the D ring (far left) to the bright A and B rings visible in small telescopes from Earth. NASA/JPL-Caltech/SSI

Cassini and the Huygens probe undergo pre-launch testing in 1996 at NASA's Jet Propulsion Laboratory in Pasadena, California. NASA/JPL-Caltech

by the moon Dione. The May 2007 discovery of Anthe outside Mimas' orbit brought the total to 60 — so far.

Ring king

Saturn's beautiful rings are one of the most recognizable features in the solar system. The orbits during the last year of Cassini's prime tour were especially good for observing rings — the spacecraft flew nearly over the poles of Saturn at inclinations greater than 70°.

The main rings (A, B, C, and D) spread over roughly 300,000 miles (480,000 km), yet they're perhaps less than about 30 feet (10m) thick. They comprise billions of spinning ice particles, ranging from pea- to house-sized.

Saturn's less well-known rings include the dynamic F ring, which sometimes appears kinked and braided; the tenuous G ring, which includes a dense arc; and the E ring, sustained by particles ejected from the moon Enceladus.

The Cassini spacecraft returned stunning data about Saturn's main rings just after its arrival at Saturn June 30, 2004. Shortly after the Saturn orbit insertion maneuver, the spacecraft obtained high-resolution images and radial profiles of ring structure in many wavelengths. Discoveries included fine-scale structure never seen before: strawlike clumps several kilometers long in the A ring; an oxygen atmosphere just above the rings; the signatures of marble-sized meteoroids impacting the rings; and evidence for slowly rotating ring particles.

Both the bright A and B rings contain more particles than planetary scientists once thought. Cassini's ultraviolet imaging spectrograph found that the particles stick together and form long, parallel, stringy clumps that are regularly torn apart and reassembled by Saturn's gravity. Because the particles aren't distributed uniformly, scientists may have underestimated the rings' total mass by up to 3 times.

Propeller-shaped structures found in Saturn's A ring may point to the locations of tiny, unseen moonlets as small as 300 feet (100m) across. As many as 10 million of these objects could orbit within the A ring. They may be the remnants of the original material that formed the rings.

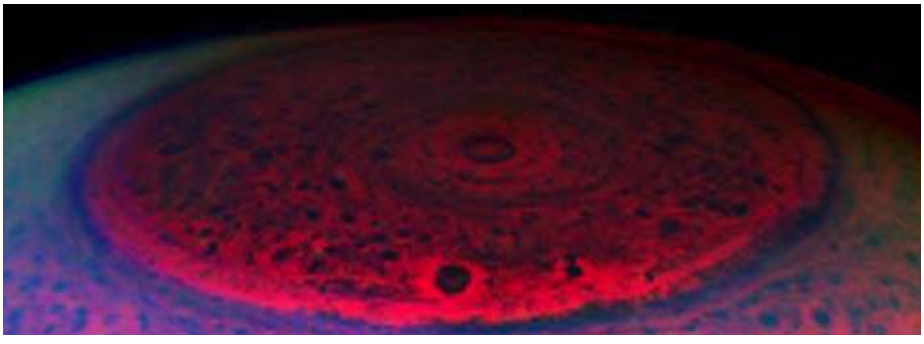
Saturn's narrow, dusty F ring continues to change as scientists watch it. Collisions in the F ring, which happen almost daily, create dusty jets. Prometheus, one of the two small moons whose gravity controls the debris, regularly steals particles from the F ring.

The G ring contains an arc of bright material that is tightly confined to the ring's inside edge. Normally, this material would smear out over time. But a gravitational resonance with the moon Mimas appears to maintain the arc.

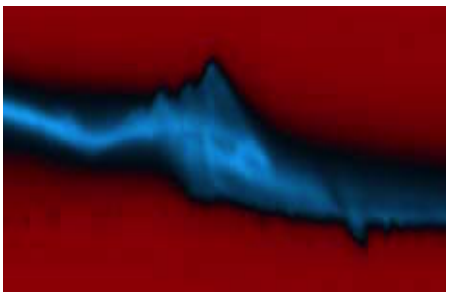
Cassini found many new rings within the Saturn system. One is associated with the tiny moon Atlas, orbiting just outside Saturn's A ring. Another tracks the so-called co-orbital moons, Janus and Epimetheus. Rings or arcs also share orbits with Methone and Pallene. It's likely that impact debris from these moons create their associated rings.

Stormy Saturn

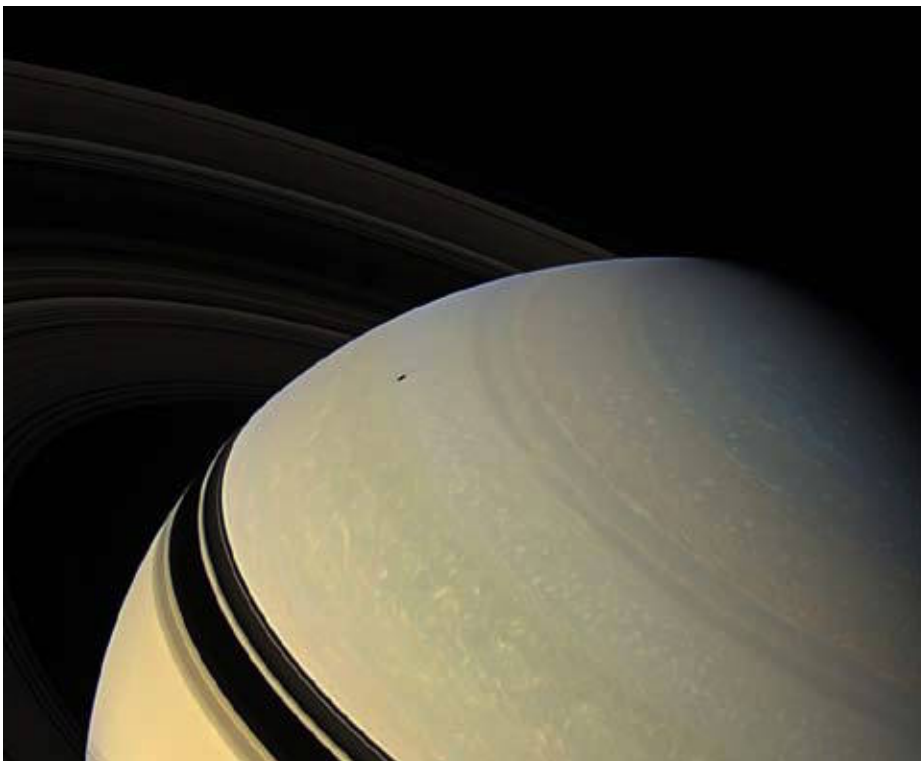
Saturn is a ball of gas more than 75,000 miles (120,000 km) across. Its volume could hold more than 700 Earths. Hydrogen and helium make up most of the atmosphere, which contains trace amounts of ammonia, methane, and phosphine.



Dark streaks, spots, and globe-encircling bands appear in this false-color infrared view of Saturn's south polar region. The deep clouds, likely made of ammonium hydrosulfide, can't be seen in daylight, but Saturn's 5.1-micrometer thermal glow shows them in silhouette. NASA/JPL/Univ. of Arizona



Strange plumes in the F ring arise when moonlets collide with dense material in the ring's core. Scientists say the F ring may be the only location in the solar system where large collisions occur daily. NASA/JPL-Caltech/SSI



The solar system's ringed beauty is approaching its equinox, when the Sun will cross directly over the planet's equator. For Cassini, this is an opportunity to look for any warps in the rings and to watch the core B ring particles heat up as they see sunlight for the first time in almost 15 years. NASA/JPL-Caltech/SSI

Where there's an atmosphere, there's weather — and Saturn's is strange, indeed.

Cassini has observed massive thunderstorms, some lasting 6 months or more, in a southern hemisphere region mission scientists call "Storm Alley." These powerful electrical storms resemble those on Earth, but they're much larger — thousands of miles across. Lightning flashes produce radio signals Cassini can link to specific storm systems. The spacecraft's radio and plasma wave instrument tracks these systems whenever they're in view. Cassini will be monitoring how the changing seasons alter Storm Alley's activity.

Both saturnian poles sport unusual features. A hurricanelike storm encircles Saturn's south pole, complete with a well-developed eye and a halo of towering clouds. This so-called polar vortex spans 5,000 miles (8,000 km) across — about two-thirds Earth's size. Within it, clockwise winds howl at 350 mph (550 km/h). The temperature of the pole itself is a few degrees warmer because the atmosphere descends there and becomes compressed and heated.

Something different occurs in the opposite hemisphere, where a hexagonal vortex 15,000 miles (24,000 km) across straddles the north pole. The Voyager 1 and 2 spacecraft first spotted the hexagon during their flybys in the 1980s, so the feature is long-lived. Because it's still winter at the north pole, the hexagon is in darkness, but infrared images indicate it extends almost 60 miles (100 km) below the cloud tops. Viewing this feature in sunlight is a top priority for the Cassini Equinox Mission.

Another priority is pinning down the length of Saturn's day. Knowing a planet's rotation rate is crucial to determining its wind speeds, and Saturn is the only planet whose exact spin remains unknown.

Space probes measure Saturn's rotation rate by detecting periodic variations in the planet's radio emissions. As Cassini approached in 2004, mission scientists measured its rotation at 10 hours, 46 minutes. This was a surprise because it indicated Saturn had slowed by 6 minutes since the Voyager flybys. Perhaps the solar wind or particles from Enceladus' icy jets alter these radio emissions in some way we don't yet appreciate.

Cassini's next 2 years will build on its previous successes. The probe will make 26 more flybys of Titan and sweep past Enceladus seven more times, with additional flybys of Dione, Rhea, and Helene. Cassini's new mission will monitor the seasons on Titan and Saturn, explore new places within Saturn's magnetosphere, and observe unique ring events, such as when the equinox Sun crosses through the ring plane next year.

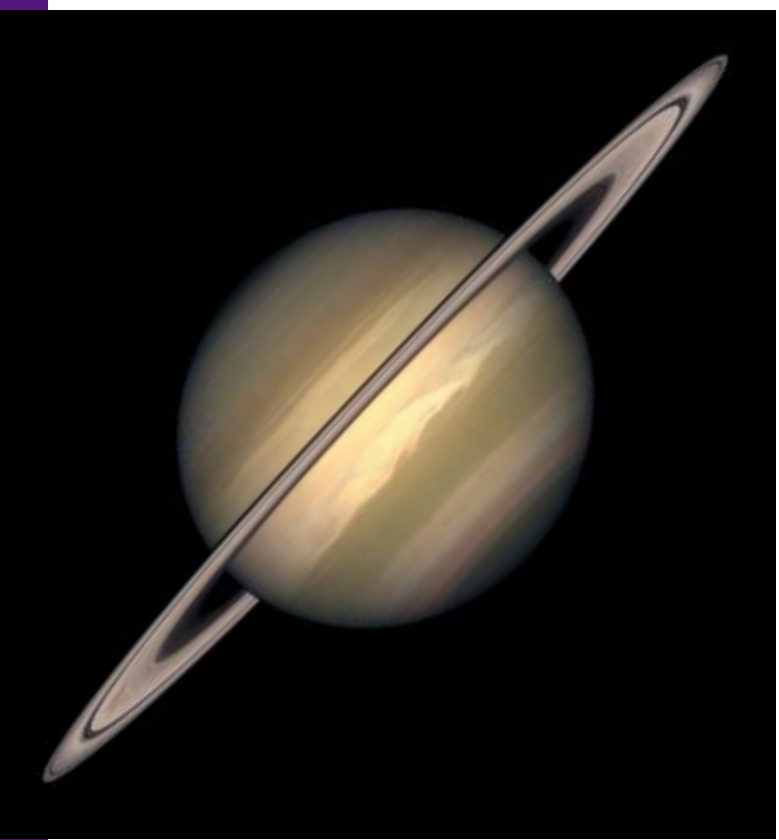
What will this avalanche of new images and measurements ultimately reveal about the Saturn system? If Cassini's first 4 years are any guide, planetary scientists should expect the unexpected.

The sky this month

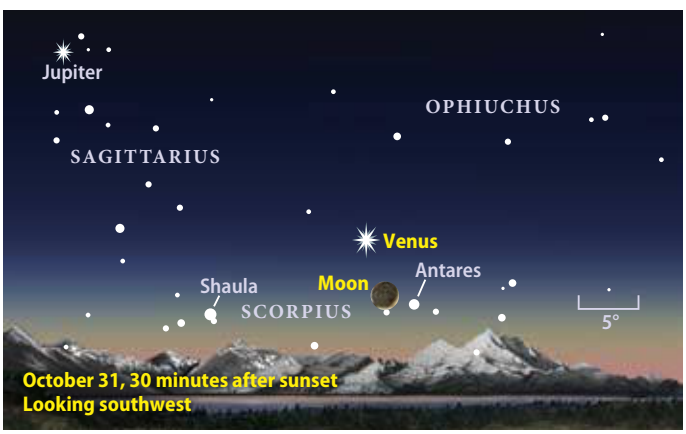
Martin Ratcliffe and Alister Ling describe the solar system's changing landscape as it appears in Earth's sky.

October 08

October's planetary bookends



Saturn's rings turn nearly edge-on to our line of sight late this year, giving observers good views of the planet's golden globe. NASA/ESA/ Hubble Heritage Team (STScI/AURA)



The Moon joins Venus on All Hallow's Eve. Look more closely, and you should spy ruddy Antares next to the Moon. *Astronomy*: Roen Kelly

There's a double serving of fine planets at dusk and dawn in the October sky. The solar system's two largest planets are like bookends to the story of the night, with Jupiter setting in early evening and Saturn rising before dawn. The two inner planets appear at opposite ends of the night as well. Venus' position improves in the evening sky, while Mercury puts on its best morning appearance of 2008.

Let's begin our story on page 1, which opens with **Venus** visible low in the west-southwest shortly after sunset. Shining brilliantly at magnitude –3.9, it quickly pops out of the fading twilight. On October 1, Venus stands 7° above the horizon 30 minutes after sunset. It sets less than an hour later.

A telescope then reveals Venus' 86-percent-lit globe, which spans 12". Little changes telescopically for Venus during October. The planet's disk grows marginally larger, while its illumination diminishes slowly, reaching 79 percent by month's end.

On the 6th, Venus passes 1° south of 3rd-magnitude Zubenelgenubi in Libra. By the 26th, the planet comes near a more eye-catching companion: the 1st-magnitude star Antares in Scorpius. Venus slides 3° north of the orange-hued star that evening. Even better, the planet appears noticeably higher at this time than it did early in the month, lying 11° above the southwestern horizon half an hour after sunset. Venus also shines a bit brighter then, having reached magnitude –4.0.

A slender crescent Moon joins Venus twice during October. On the 1st, a 2.5-day-old Moon passes 5° south of Venus. Head out half an hour after sunset and scan to Venus' lower left with binoculars. You should see the Moon 3° above the horizon.

October 1 also might be your last chance for several months to spot **Mars**. The Red Planet lies at the same altitude as the Moon, but significantly farther north. You'll need an observing site that with a clear

— *Continued on page 61*

40 Saturn's edgy rings
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63 Mercury bright before dawn

Visible to the naked eye
Visible with binoculars
Visible with a telescope

Astronomy's guide to Go-to telescopes

We look at 23 of the best, plus a special section on seven CCD cameras.

by Phil Harrington

Astronomy magazine
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True Ritchey-Chrétiens starting at only $1295.
That price is NOT a misprint.

AT8RC Astro-Tech 8" R-C

Until now, the coma-free optics of *true* Ritchey-Chrétien optical systems came only in large apertures and their prices typically *started* at well over $10,000. That put a true R-C astrograph out of the reach of most astrophotographers.

But **Astro-Tech** knew that state-of-the-art computerized mirror grinding machines could shape and polish the complex hyperbolic mirrors of a Ritchey-Chrétien with the precision that serious astrophotographers demand. They knew that buying in quantity would bring the cost of premium quartz mirrors and carbon fiber optical tubes down to a reasonable price range. And they knew that CNC machining the mechanics would produce the first-line fit, finish, and reliability you expect from Astro-Tech.

That's why Astro-Tech is proud to introduce the Astro-Tech RC Series – top-quality *true Ritchey-Chrétien* astrographs at prices you don't have to be a millionaire to own.

Astro-Tech AT6RC: A 6" f/9 ideal for coma-free imaging with webcams, Deep Sky Imager-type cameras, and ST-7/8/9-class CCDs. Aluminum tube, BK-7 mirrors, 1/12th wave or better optics, Crayford focuser, Vixen-style dovetail, dust cover **$1295**

Astro-Tech AT8RC: An 8" f/9 for imaging with 35mm large format (STL-type) CCD cameras and long imaging equipment trains. A light weight/high strength *carbon fiber* tube, quartz mirrors, *dielectric* mirror coatings, 1/12th wave or better optics, genuine *Feather Touch* focuser, case, Losmandy-style dovetail, dust covers **$2995**

Astro-Tech AT10RC: A 10" f/9 with the same features as the AT8RC, but with a larger aperture and two cooling fans. Compare at $14,000 ..... **approximately $4995**

Also in development are 12" and 16" Astro-Tech Ritchey-Chrétiens. Prices have yet to be finalized, but they will be sensibly and affordably-priced in line with the prices of the Astro-Tech R-Cs above. Their prices will make you wonder why the competition charges as much as $17,000 for a 12.5" R-C and $34,000 for a 16".

Three TMB triplet apos in stock starting at $995.

$3999 TMB-130 triplet apo

The 130mm f/7 **TMB-130** apochromatic triplet, left, is a *Hot Product for 2007.* Unlike other ultra-premium refractors that have multiyear waiting lists, this big apo is available now.

$1999 TMB-92 triplet apo

The ultra-compact (only 13.25" long!) 92mm f/5.5 **TMB-92** triplet apo, right, expertly fills the void left by the discontinued 90mm Astro-Physics Stowaway (a legendary refractor that sells for up to $6000 on the used market). But the new TMB-92 is only $1999 – *and it's available now.*

$995 TMB-80 triplet apo

Both of the above scopes have collimatable lens cells, FPL-53 ED glass, a genuine *FeatherTouch* dual-speed rotating rack and pinion focuser, compression ring eyepiece holders, carrying case, and more.

The **TMB-80**, right, is an 80mm f/6.3 triplet apo with FPL-53 glass for only $995! It's the first time a genuine TMB apo refractor has been available at such an attractive price. A true TMB for under $1000? Wow!

TeleVue 100° field 8mm Ethos. $585 and worth it.

Few eyepieces have received as many rave reviews as the $620 100° field 13mm TeleVue Ethos. It proved that an eyepiece costing as much as many complete scopes was indeed worth the money. Now the 13mm is joined by the **TeleVue 8mm Ethos**. Let the rave reviews begin all over again.

The Celestron NexStar SE scopes are four of the best values in astronomy.

$799
Celestron NexStar 5SE 5" Schmidt-Cassegrain

Many of the advanced features in the very complete **Celestron NexStar SE** go-to telescopes were unavailable at *any* price only a few years ago.

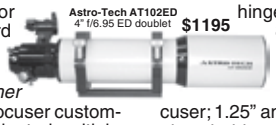
For example, their *SkyAlign* go-to computers make astronomy easy as 1-2-3. Just point your scope at three bright stars (or two stars and the Moon or a planet) to line it up on the sky so it can find 40,000 celestial objects for you. You don't even have to know which stars they are!

And their Starbright XLT optical multicoatings give you the brightest images and highest contrast ever, so you can see more, and see it better!

Is a Celestron NexStar SE a great value? *Absolutely!*

NexStar 4 SE, 4" Maksutov **$599**
NexStar 5 SE, 5" Schmidt **799**
NexStar 6 SE, 6" Schmidt **999**
NexStar 8 SE, 8" Schmidt **1399**

Competitors? At $1195, the Astro-Tech 102ED has none.


Astro-Tech AT102ED 4" f/6.95 ED doublet **$1195**

No competitive refractor gives you as many standard features for $1195 as the **Astro-Tech AT102ED**.

You get a genuine *Feather Touch* dual-speed micro-focuser custom-made for the 102ED*; illuminated multiple reticle finder*; locking hard case*; dual hinged tube rings with separate 8" dovetail*; 102mm f/6.95 ED doublet optics; retractable dew shield with lock knob*; rotating Crayford focuser; 1.25" and 2" compression ring eyepiece holders; *2-year* warranty*; more.

Competitive scopes just can't compete.

*Features marked with asterisks are either optional or unavailable with some or all competitive refractors.

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The Astro-Tech Voyager – "a really sweet grab-and-go."

$299
Astro-Tech Voyager with optional Astro-Tech 4" AT102ED

A recent magazine review said the $299 **Astro-Tech Voyager** altazimuth mount was "unusually stable for its size and weight" and was packed with "lots of first-class engineering" that made it "a really sweet grab-and-go setup that's ideal for viewing day or night."

The Voyager has a 20 pound payload capacity, automatic clutch worm drive manual slow motion controls, adjustable height aluminum tripod, Vixen-style dovetail, and a very affordable price. The Voyager is clearly today's best buy in altazimuth mounts.

Even better, buy *any* scope from Astronomics, and a Voyager is yours for only $249.

Celestron CPC Schmidt-Cassegrains . . . affordable, available, and easy to use.

Celestron 8" CPC800 **$1999**

It's easy to find your way around the sky with a **Celestron CPC** go-to telescope. Just point it at any three bright lights in the sky (3 stars, or 2 stars and a planet or the Moon), and your CPC finds over 45,000 deep space and solar system objects for you at the touch of a button.

You don't have to enter your time or location or memorize a star chart to use a CPC. Its built-in GPS and a few anonymous lights in the sky are all you need.

Celestron CPC Schmidt-Cassegrains, with advanced Starbright XLT multicoatings, come with all the features you need to start go-to observing immediately.

8" **CPC800**, with XLT multicoatings **$1999**
9¼" **CPC925**, with XLT multicoatings **2499**
11" **CPC1100**, with XLT multicoatings **2799**

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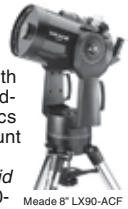
A Meade LX90 has "Ritchey-Chrétien-like" optics at a price that's not too rich.


Meade 8" LX90-ACF **$1999**

Sky & Telescope said that Meade's original Advanced Coma-Free f/8 catadioptric go-to scope "does indeed perform like a Ritchey-Chrétien." And *Astronomy* said it "delivers Ritchey-Chrétien-like performance at a fraction the cost."

Meade LX90-ACF go-to catadioptric scopes have f/10 versions of those same highly reviewed coma-free optics, but at prices that make "Ritchey-Chrétien-like" optical performance truly affordable.

A Meade LX90-ACF with "Ritchey-Chrétien-like" Advanced Coma-Free optics *and* a full GPS go-to mount starts at only $1999!

Here are the *freight-paid* prices for the Meade LX90-ACF catadioptric scopes:

8" LX90-ACF, Advanced Coma-Free **$1999**
10" LX90-ACF, Advanced Coma-Free **2699**
12" LX90-ACF, Advanced Coma-Free **3299**

Great Astro-Tech eyepiece values from $39.95 to $99.95.

Series 6 20mm

Titan 2" 38mm

These new Astro-Tech eyepieces are good examples of the Astro-Tech philosophy of giving you "more performance for less money."

The **Astro-Tech Series 6** 1.25" eyepieces, above left, have wide 60° and 65° fields at only $39.95 each. Fully multicoated, with fold-down rubber eyecups, they are inexpensive enough to buy two at a time for binoviewer use.

Series 6 – 1.25," 60° field, 8 or 12mm ... **$39.95**
Series 6 – 1.25", 65° field, 17 or 20mm ... **39.95**

The **Astro-Tech Titan** 1.25" and 2" eyepieces (the 2" 38mm is to the left) all have wide 70° fields, twist-up rubber eyecups, good eye relief, and none is priced higher than $99.95.

Titan – 1.25", 70° field, 10 or 15mm . **$59.95**
Titan – 1.25", 70° field, 20mm **69.95**
Titan – 2", 70° field, 26mm **79.95**
Titan – 2", 70° field, 32mm **89.95**
Titan – 2", 70° field, 38mm **99.95**

Are the Astro-Tech eyepieces great values? Does the sun rise in the east? The answer to both questions is yes!

Better do in dew before dew do in you.

$105
4 output/2 channel AstroZap dew heater controller

AstroZap aluminum and flexible plastic dew shields *slow* the formation of dew that can shorten your viewing time and ruin your astrophotography sessions. Prices start at only $24.95, making economical AstroZap dew shields our best-sellers.

Even better, AstroZap dew heaters and heated dew shields can totally eliminate dew *before* it ruins your viewing. Dew heater strips start at only $25, and heated dew shields start at only $49.95.

Point, click, and the sky is yours for $299.

Meade mySKY **$299**

The **Meade mySky** locates and identifies 30,000 celestial objects with point and click ease. This great gift idea shows you full-color images of many of them on its built-in LCD screen, with videos, sky maps, and text, while music and narration play through its supplied earbuds.

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One of the most important decisions an amateur astronomer can make is choosing which telescope to buy. But as a person begins to survey the marketplace, it quickly becomes apparent that the optical tube is only half of the equation. It is just as important to choose the right telescope mount. A mount must be sturdy enough to support the telescope's weight and move smoothly, while minimizing vibrations.

Two basic telescope mounts — alt-azimuth and equatorial — have been around for centuries. Recently, each has evolved dramatically thanks to computerization. When coupled with an onboard computer, many modern mounts can point their optical tubes at thousands of sky objects programmed into their electronic brains. These telescopes are nicknamed "go-to" because once you tell them what you want to observe, they will automatically turn toward those objects.

Phil Harrington *is a contributing editor of* Astronomy. *Find his column, "Phil Harrington's Binocular Universe," on page 85.*

To locate sky objects, a mount must know the time, date, and location. Some systems require the observer to enter this data using a small, handheld control box. Others gather it by built-in Global Position System (GPS) technology and electronic compasses.

After receiving signals from orbiting GPS satellites, receivers in these instruments can figure out not only the time, date, and location, but also determine true north and whether or not the mount is level.

Once the computer has this data, it then chooses the first of two alignment stars and guides the telescope to its general location. The observer must center the star using the controller. After repeating the process with the second alignment star, the telescope is ready to "go-to" for the evening.

Is there a difference in pointing and tracking accuracy between go-to alt-azimuth and equatorial mounts? The short answer is no. Both are accurate, but each has its own advantages.

One difference is in setting up the mount. Alt-azimuth go-to mounts are the easiest. Just place them pretty much anywhere as long as they don't rock back and forth on uneven terrain.

With an equatorial go-to mount, you must roughly align it with the celestial pole. The models listed here make this easy because they accept alignment scopes. But unless you are an astrophotographer, an alignment scope is not necessary. Simply peek through the hollow polar-axis housing. Then, move the mount's base left or right, and adjust its tilt up or down until you can see Polaris (Alpha [α] Ursae Majoris), the North Star.

Another consideration is that you accurately initialize the mount. Although many mounts allow one-star alignment, you'll get better results by using two or three stars. More is always better than less.

Now that you know what a go-to scope is, which one is right for you? With more than 150 different models on sale, the choice can be daunting. To help you, I've put together a list of some of today's best go-to scopes.

Refractors

Astro-Physics StarFire EDF

Astro-Physics has earned a reputation for fine apochromatic (highly color-corrected) refractors and rock-steady mounts. That tradition continues with the company's new 5.1-inch f/6.3 130 StarFire EDF and Mach1 GTO German equatorial mount.

This dynamic duo is small enough to transport easily to a dark site, yet sturdy enough to let you take striking astrophotos. The Mach1 GTO's extensive catalog of sky objects can be customized based on size, brightness, and other parameters.

Refractors

Meade AR-5 AT

Meade's 5-inch f/9 AR-5 AT is great for someone on a budget. The LXD75 German equatorial mount that comes with the AR-5 is quite sturdy, thanks to internal steel ball bearings and a tripod with tubular stainless steel legs. Meade's Autostar go-to control consistently gets objects in the field of a low-power eyepiece, while the included Periodic Error Correction (PEC) control is a bonus for astroimagers.

Meade ETX-80AT-TC Backpack Observatory

Looking for a lightweight grab-and-go-to scope? Meade's ETX-80 AT-TC, which combines a 3.2-inch f/5 refractor with a small alt-azimuth mount, may be just the ticket for locating the more than 1,400 sky objects in its computer database.

Insert the supplied 26mm Plössl eyepiece, and the ETX-80 will show great views of star clusters and nebulae. The included 9.7mm Plössl eyepiece attached to the built-in flip Barlow lens supplies enough magnification to enjoy a visit to the Moon's craters and the bright planets.

Celestron NexStar 102 SLT

The 4-inch f/6.5 NexStar 102 SLT rides on a one-armed alt-azimuth mount. Although a wide-field scope by nature, the 102 SLT easily handles magnifications up to 150x for great views of Jupiter and its moons and Saturn's nearly edge-on rings. The 102 SLT's SkyAlign microprocessor contains data and finding instructions for more than 4,000 targets, including the Moon, the planets, and a host of deep-sky objects.

Vixen 102M Sphinx

The 4-inch f/9.8 Vixen 102M refractor mounted on the sophisticated Sphinx equatorial mount takes go-to control to the next level. Rather than using a simple push-button hand control, Vixen includes a self-contained digital planetarium called the Star Book.

Set the Star Book to the time, date, and location, and its LCD screen shows the sky exactly as it appears. Move the cursor using the toggle buttons, press "go-to," and the telescope heads to the selection.

Orion 100ED Go-To

Orion's 100ED is one of its most popular apochromatic (highly color-corrected) refractors. It boasts high-quality optics in an attractive package. The 100ED is available on either the SkyView Pro or Sirius EQ-G Go-To German equatorial mounts.

The SkyView is great for visual use and rudimentary astrophotography. The heavy-duty equatorial head and tripod of the Sirius mount is perfect for intermediate amateurs with digital cameras.

Takahashi TSA-102S/ EM-11 Temma-2 Jr.

One of Takahashi's newest telescopes is the 4-inch f/8 TSA-102S apochromat. The front lens of this scope is a highly corrected triplet.

While you can attach the TSA-102S to several different mountings, Takahashi's EM-11 Temma-2 Jr. seems the perfect choice. It offers complete go-to control when connected to the Takahashi hand controller (sold separately) or a personal computer. It is one of the sturdiest telescope mounts available in its size class.

REFRACTOR COMPARISON

Manufacturer/Model	Aperture	f/ratio	Street price
Astro-Physics StarFire EDF	5.1"	f/6.3	$5,675
Celestron NexStar 102 SLT	4"	f/6.5	$479
Meade AR-5 AT	5"	f/9	$999
Meade ETX-80AT-TC Backpack Observatory	3.2"	f/5	$299
Orion 100ED Go-To	4"	f/9	$1,149.95
Takahashi TSA-102S EM-11 Temma-2 Jr.	4"	f/8	$7,299
Vixen 102M Sphinx	4"	f/9.8	$3,090

Reflectors

Celestron C8-NGT

Celestron's 8-inch f/5 C8-NGT comes on the sturdy Advanced Series CG-5GT mount. The CG-5's NexStar Go-To system gets high marks for pointing accuracy, and the telescope earns equal raves for optical excellence.

Because of the go-to drive's power requirements, Celestron does not include a battery holder, as some others do. Instead, the company wisely supplies a 24-foot cord to plug into an automobile's cigarette lighter or rechargeable battery. A 110-volt AC adapter is also available separately.

JMI NGT-18

JMI's Next Generation Telescope (NGT) series breaks the recent tradition of mounting large Newtonian reflectors on Dobsonian mounts. Instead, the company combines an open-truss tube assembly with a split-ring equatorial mount.

To steer the 18-inch f/4.5 NGT-18, JMI relies on the popular ServoCat electronic control package from StellarCAT and the Argo Navis hand-held computer from Wildcard Innovations. The size of a traditional German equatorial mount for this class of instrument would relegate it to permanent observatory installation. But the sleek, low-profile NGT can be disassembled and carried in the back of a station wagon for trips to remote locations.

Obsession 15

Obsession reflectors range in aperture from 12.5 to 30 inches. Of those, the 15-inch f/4.5 Obsession 15 seems an optimal size. It is small enough to transport in the back of most cars and can be set up easily by one person. But it is still large enough to show deep-sky objects in stunning detail.

Like JMI (left), Obsession's telescopes use the ServoCat dual-axis motor system coupled to the Argo Navis controller. The result is a large-aperture Dobsonian-mounted reflector that can steer itself to tens of thousands of celestial targets.

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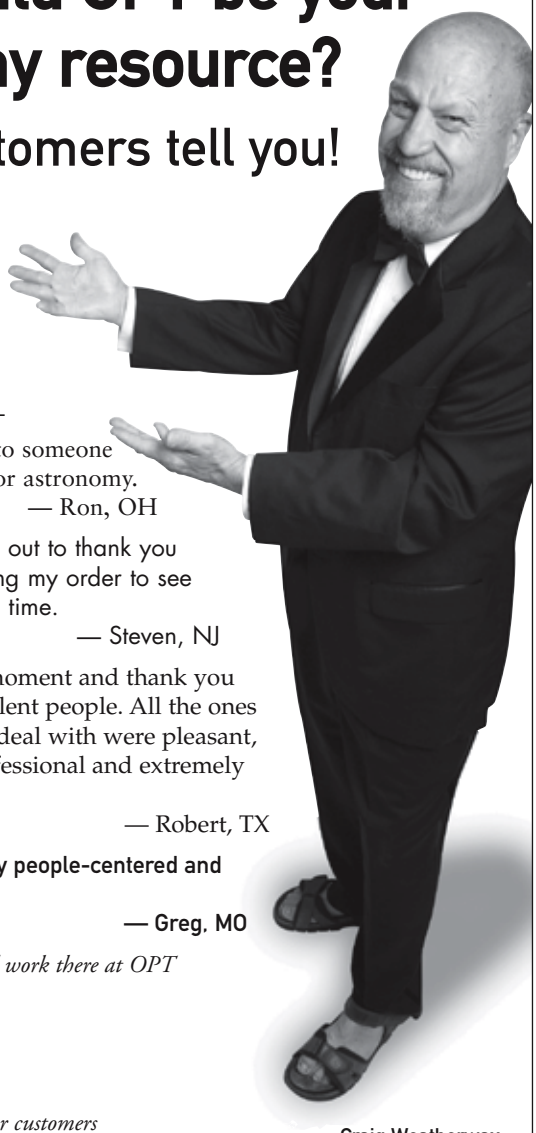

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Voyager is "a really sweet grab-and-go setup."

$299

A magazine recently called the Astro-Tech Voyager altazimuth mount "unusually stable for its size and weight" and said it was packed with "lots of first-class engineering" that made it "a really sweet grab-and-go setup that's ideal for viewing day or night."

Astro-Tech Voyager shown with an optional **Astro-Tech AT102ED** 4" refractor

The Voyager has automatic friction clutches that let you quickly point your scope at a target manually, then smoothly track it in any direction using Voyager's dual 120-tooth worm gear 360° manual slow-motion controls.

The review said the value of Voyager's "smooth slow motion controls" was "immediately obvious . . . Couple them with the Voyager's stability, and it was a pleasure viewing at magnifications approaching 200x – something I can't say for most alt-azimuth mounts that you have to push by hand."

The all-metal adjustable-height Voyager weighs a very transportable 13.75 pounds, yet has a 20 pound payload capacity. The "really sweet" $299 Astro-Tech Voyager is clearly the new leader in altazimuth mount value.

A 2007 Hot Product, still hot in 2008!

$69.95

This **Astro-Tech 1.25" star diagonal**, like all Astro-Tech diagonals, has 46-layer 99% reflective *dielectric* coatings on its premium 1/10th wave BK7 optical glass substrate. 2" Astro-Tech BK7 dielectrics start at $119.95, *quartz* at $189.95.

A review in Astronomy said everyone should own the AT66ED.

$359

The review said "While I'd normally have reservations about recommending a scope with less than 3 inches of aperture, every once in a while there comes a product everyone should own. This apochromatic doublet is just such a beast . . . The short focal length makes it a wonderful tool for scanning the Milky Way, and its small aperture and FPL-51 glass let you crank up the magnification on the Moon without false color becoming too intrusive. The AT66ED can serve as a great grab-and-go scope, a fine little astrograph, a super-finder scope, and a daytime spotting scope."

For $359 you get ED doublet apo optics, a rotating dual-speed focuser, 1.25" compression ring eyepiece holder, hard case, and a photo tripod mounting shoe that also fits onto Celestron, Meade, and Vixen mounts.

The **Astro-Tech AT66ED** is available in black, white, red, blue, or green.

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Orion SkyQuest XT6 IntelliScope

Rather than relying on batteries, motors, and gears to steer it, Orion's SkyQuest XT IntelliScope "push-to" Newtonians depend on observers to move them. The intelligence behind the 6-inch f/8 XT6 comes from a pair of built-in digital encoders and a hand-held Computerized Object Locator.

Except for the 9-volt battery for the locator, IntelliScopes need no power. After you select from more than 14,000 sky objects in the computer's memory, a pair of directional guide arrows and incremental numbers pop onto the controller's screen. Push the telescope in the direction of the arrows until the numbers drop to 0.0, and the target should show up in the eyepiece field.

Orion Atlas 8 EQ-G

Orion combines many optical tubes with its heavy-duty Atlas-G equatorial mount. The 8-inch f/4.9 Newtonian reflector is an ideal pairing.

The pointing and tracking accuracy of the mount's internal stepper motors is exceptional. Couple that with the 8-inch's fast f/4.9 focal ratio, computerized control, periodic error correction, and ability to plug in an autoguider for hands-free imaging, and you have an excellent package for observing and photographing the universe. Although the Atlas 8 EQ-G tips the scales at 96 pounds, its intelligent design helps ease the burden of transportation and setup.

Starmaster Hybrid Go-To 12.5

Starmaster was the first to successfully incorporate a fully computerized go-to system into its Dobsonian mounts. Known as the Sky Tracker go-to-then-track drive system, it works like the ServoCat system used by JMI and Obsession.

Although the Sky Tracker is available as an option on all Starmaster telescopes, Starmaster's 12.5-inch f/4.3 Hybrid Truss is a great compromise between aperture and overall instrument size. The upper cage and eight truss poles can be preassembled and the entire unit lifted onto the mirror box, where it is attached with four thumb knobs. This convenience makes setup and tear-down quick.

REFLECTOR COMPARISON

Manufacturer/Model	Aperture	f/ratio	Street price
Celestron C8-NGT	8"	f/5	$1,019
JMI NGT-18	18"	f/4.5	$15,900
Obsession 15	15"	f/4.5	$7,590
Orion Atlas 8 EQ-G	8"	f/4.9	$1,399.95
Orion SkyQuest XT6 IntelliScope	6"	f/8	$499.95
Starmaster Hybrid Go-To 12.5	12.5"	f/4.3	$2,195

Catadioptrics

Celestron CPC 9.25

Celestron's line of Celestron Professional Computerized (CPC) models includes the 9.25-inch f/10 C9.25 Schmidt-Cassegrain telescope. The CPC alt-azimuth fork mount features Celestron's SkyAlign go-to system. Once the computer gets the date, time, and location from GPS satellites, the user initializes the telescope by aiming it at three random stars. No need to tell the system which star is which. The computer calculates the angles measured between the objects and compares them to angles between known objects. That's it; the scope is ready to go-to.

Celestron C8-SGT

One of the most versatile and popular German equatorial mounts sold today is the Celestron Advanced Series CG-5GT. Its incarnation as the C8-SGT, which places one of Celestron's 8-inch f/10 Schmidt-Cassegrain telescopes on top, is a great choice for anyone looking for that first "serious" scope to bring to a dark-sky site. The NexStar-driven CG-5GT has two jacks: one for adding the optional CN16 GPS accessory, which ties the onboard computer to the global positioning system, and another for an autoguider.

Celestron NexStar 6SE

You can distinguish Celestron's 6-inch f/10 NexStar 6SE Schmidt-Cassegrain telescope by its one-arm alt-azimuth mount. Celestron housed all of the go-to circuitry within that arm. The NexStar hand controller also nests there. The result is a compact, lightweight instrument, great for apartment dwellers or anyone looking for a telescope that you can carry up and down a flight of stairs with one hand.

Celestron CGE 1400

Celestron's flagship telescope, the 14-inch f/10 Celestron 14, is the largest of four apertures available on the massive CGE German equatorial mounting. If you are looking for a state-of-the-art telescope to put in a backyard observatory, this instrument should be on your short list. The CGE mount is substantial enough to hold the 14-inch steady for guided astrophotography, and it's also great for visual observing.

Catadioptrics

Meade ETX-90PE

The 3.5-inch f/13.8 Meade ETX-90PE Maksutov-Cassegrain, called the Premiere Edition, places the telescope atop a miniaturized, computer-driven fork mount. Meade's DC-powered Autostar go-to computer accurately points the ETX toward thousands of sky objects when you initialize the instrument. Simply input your location by name, coordinates, or ZIP code. The telescope then aligns itself to magnetic north using its internal compass, calculates true north, and slews to the first of two alignment stars. Center each of the stars in the instrument's SmartFinder and start observing.

Meade 10-inch LX200-ACF

Meade's Advanced Coma-Free (ACF) telescopes range in aperture from 8 to 16 inches. Each uses an optical design that improves image sharpness by eliminating the optical defect coma.

Of all the instruments in the ACF line-up, the 10-inch f/10 model strikes the best balance between aperture and portability. It comes on an alt-azimuth fork mount equipped with Autostar II control. The SmartDrive system automatically aligns itself using data from global positioning satellites. Pointing accuracy is excellent, consistently placing targets in the eyepiece field of view.

Meade 10-inch LX90-ACF

If you want the benefits of Meade's ACF (Advanced Coma-Free) optical design, but do not need the advanced features of the LX200 mount, the LX90-ACF line is perfect. Like the LX200, the 10-inch LX90 strikes a balance between aperture and weight if you set up the instrument before each use.

The LX90 mount features the same Autostar II control as its big brother, which is easy to initialize and use. The internal GPS receiver automatically determines your time and location. The integrated compass levels the optical tube and points it north, and the AutoStar computer does the rest.

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Catadioptrics

Meade SN-8 AT

If you're looking for a different optical design, Meade offers three Schmidt-Newtonian telescopes: the 6-inch f/5 SN-6 AT, 8-inch f/4 SN-8 AT, and 10-inch f/4 SN-10 AT. The 8-inch version is a favorite for its convenient size and substantial aperture.

The LXD75 German equatorial mounting and AutoStar go-to system are easy to set up. The LXD75 can operate on eight D-cell batteries held in a separate power pack. If you'll be observing for more than a few hours, especially in cold weather, use Meade's external 12-volt battery or 120-volt AC adapter, both optional.

Orion SkyView Pro 180

If you want to try a catadioptric design outside the Schmidt-Cassegrain realm, a Maksutov design might suit your needs. Such telescopes produce sharp images in compact packages.

The largest go-to Maksutov on sale today is the 7.1-inch f/15 SkyView Pro 180 from Orion Telescopes and Binoculars. For observers whose primary interests are sharp, high-powered views of the Moon, planets, and close-set double stars, the SkyView Pro 180's f/15 focal ratio provides higher magnification per given eyepiece than faster telescopes.

Orion Atlas 9.25 EQ-G

For its Atlas 9.25 EQ-G, Orion couples its heavy-duty German equatorial mount to Celestron's 9.25-inch Schmidt-Cassegrain optical tube assembly to create a great go-to instrument. The robust Atlas mount steers the tube effortlessly after you roughly polar align and initialize it. If you prefer a German equatorial mount to a fork mount and are looking for great optical quality, be sure to check into Orion's Atlas 9.25 EQ-G.

CATADIOPTRICS COMPARISON

Manufacturer/Model	Aperture	f/ratio	Street price
Celestron C8-SGT	8"	f/10	$1,529
Celestron CGE 1400	14"	f/10	$6,634
Celestron CPC 9.25	9.25"	f/10	$2,499
Celestron NexStar 6SE	6"	f/10	$999
Meade ETX-90PE	3.6"	f/13.8	$699
Meade 10-inch LX200-ACF	10"	f/10	$3,699
Meade 10-inch LX90-ACF	10"	f/10	$2,699
Meade SN-8 AT	8"	f/4	$1,199
Orion Atlas 9.25 EQ-G	9.25"	f/10	$2,699.95
Orion SkyView Pro 180	7.1"	f/15	$1,549.95

Imaging

Apart from finding selected targets in its database, a go-to mount also tracks objects across the sky. Given this convenience, many amateur astronomers like to try their hands at astrophotography. Here's a look at some of today's most popular digital cameras.

> Chris Schur imaged the **Rosette Nebula** (NGC 2237–9) with the Canon digital Rebel XTi.

Canon Digital Rebel XTi

If you would rather have an all-in-one digital camera that eliminates the need for a separate computer at the telescope, Canon's Digital Rebel XTi digital single-lens reflex (DSLR) camera is a great choice. You can attach DSLRs directly to a telescope's focuser using commonly available adapters or mount them piggyback for guided photography through conventional camera lenses.

Images taken with the XTi's 10.1-megapixel chip can be enlarged to 16" by 20" without losing sharpness. Consider adding a wireless remote control to trigger the shutter, such as Canon's RC-1 or RC-5.

Apogee Alta U16M CCD

Some of the most experienced amateurs use Apogee's line of Alta CCD cameras. One of their newest imagers is the Alta U16M, which uses Kodak's KAF-16803 16-megapixel monochromatic CCD sensor.

This full-frame chip is ideal for anyone looking to photograph huge fields of view in a single step. Apogee also sells the AFW50 7S filter wheel for color imaging.

> Ken Crawford imaged **NGC 3199** with the Alta U16M CCD camera.

FLI ML8300

Finger Lakes Instrumentation (FLI) sells a number of top-of-the-line CCD cameras for amateur astronomers. Two of FLI's best products for the astroimager looking to move up to the next level are the ML8300 and ML8300-C, from the company's widely acclaimed Micro-Line image series.

The ML8300 features Kodak's 8.3-megapixel KAF8300 monochrome CCD chip, while the ML8300-C uses the CPL8300-C color chip. Like all Micro-Line imagers, the ML8300 and ML8300-C have USB computer connections for efficient image downloading at speeds up to 12 megapixels per second. Both come with external power supplies.

< Gerald Rhemann and Michael Jäger imaged **Cederblad 111** with the FLI ML8300 CCD camera.

Meade DSI III

Meade's Deep-Sky Imager III is for amateur astronomers who would like to take color images of planets or deep-sky objects, but aren't sure they want to spend a lot. Meade's third-generation Deep-Sky Imager contains a 1.4-megapixel color CCD chip that improves on the field size and resolution of previous models.

The DSI III's single-shot color capability eliminates the possibility of knocking the telescope off-target while fumbling with filters or using a color-filter wheel. Add to that the DSI III's improved thermal-noise dissipation and the included Autostar image processing software, and you have a complete, ready-to-go system.

< Mark Sibole imaged the **Andromeda Galaxy** (M31) with the Meade DSI III CCD camera.

Orion StarShoot Deep Space Imaging Camera II

Of the three digital imagers Orion sells, its StarShoot Deep Space Imaging Camera II is the most sophisticated. The StarShoot DSCI II offers an ideal introduction to digital astrophotography.

When connected to a computer, the DSCI II's Sony chip can capture some striking one-shot color images. The StarShoot DSCI II also features thermoelectric cooling to reduce image-degrading electronic noise. To complete the package, Orion includes MaxIm DL Essentials software that aids focusing, image acquisition, and post-exposure image processing.

v Joe Roberts imaged the **Moon** with Orion's StarShoot Deep Space Imaging Camera II.

Michael Sidonio imaged **NGC 1365** with the Starlight Xpress SXV-H9 CCD camera.

Starlight Xpress SXV-H9

Starlight Xpress sells some of the smallest and lightest CCD imagers on the market. One of its most popular is the SXV-H9. It uses Sony's ICX285AL monochromatic sensor to create 1.45-megapixel images.

The camera has an autoguider interface compatible with Starlight Xpress' optional external guide camera (which necessitates a separate guide scope). Each camera also has a port for operation of the optional color-filter wheel.

For those who prefer one-shot color, StarLight Xpress manufactures the SXV-H9C. Both cameras weigh less than a pound and measure 4 inches (102mm) long by 2.5 inches (63.5mm) in diameter. That makes them ideal for medium-duty mounts that heavier imagers might overwhelm.

IMAGING COMPARISON

Manufacturer/Model	CCD Chip	Street price
Apogee Alta U16M CCD	16 Mp	$9,896
Canon Digital Rebel XTi	10.1 Mp	$459
FLI ML8300	8.3 Mp	$4,995
Meade DSI III	1.4 Mp	$1,299
Orion StarShoot Deep Space Imaging Camera II	0.44 Mp	$599.95
SBIG ST-10XME	3.2 Mp	$5,995
Starlight Xpress SXV-H9	1.45 Mp	$2,995

SBIG ST-10XME

One of the first companies to introduce CCD imagers to the amateur marketplace, Santa Barbara Imaging Group (SBIG), continues to be a leader in the industry. One of SBIG's most popular models, the ST-10XME, has proved to be a great imager. Perhaps the biggest advantage to the ST-10XME is that it is self-guiding. Inside, you'll find two CCD detectors, one for guiding and the other for imaging. When connected to a suitable go-to mount, the guiding CCD chip will keep a preselected star centered, eliminating the laborious task of manual guiding. Because the ST-10XME's main imaging chip is monochromatic, you'll need an optional series of filters and a filter wheel for color astrophotography.

Dean Salman imaged **Sharpless 2–9** with the SBIG ST-10XME CCD camera.

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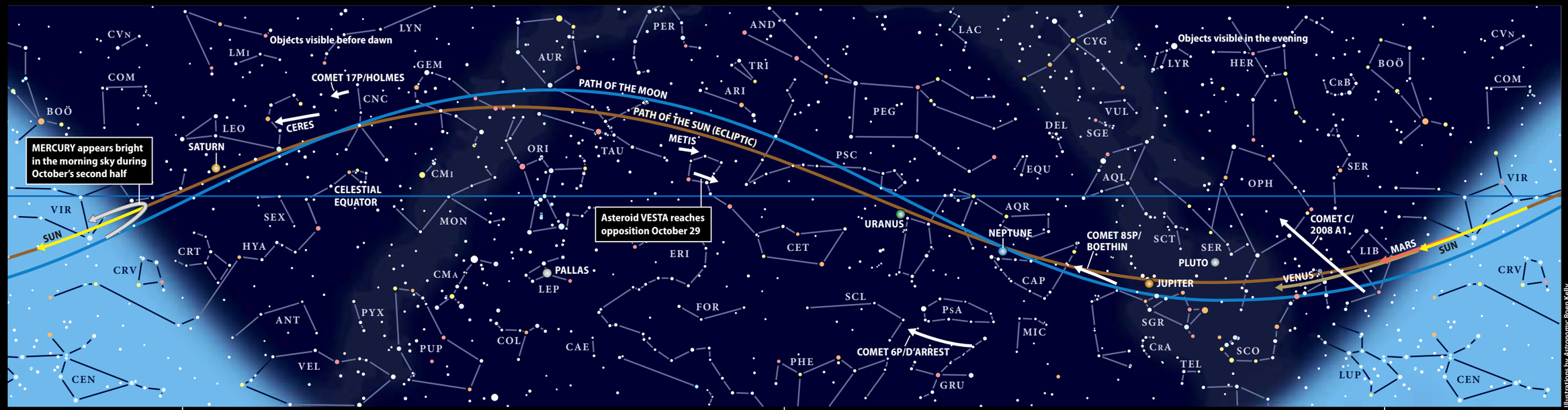
Planets in October 08

This map unfolds the entire night sky from sunset (at right) until sunrise (at left).
Arrows and colored dots show motions and locations of solar system objects during the month.

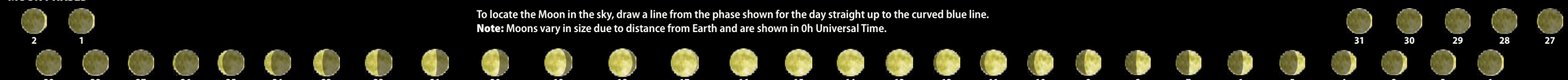
Astronomy magazine

Path of the planets



MOON PHASES

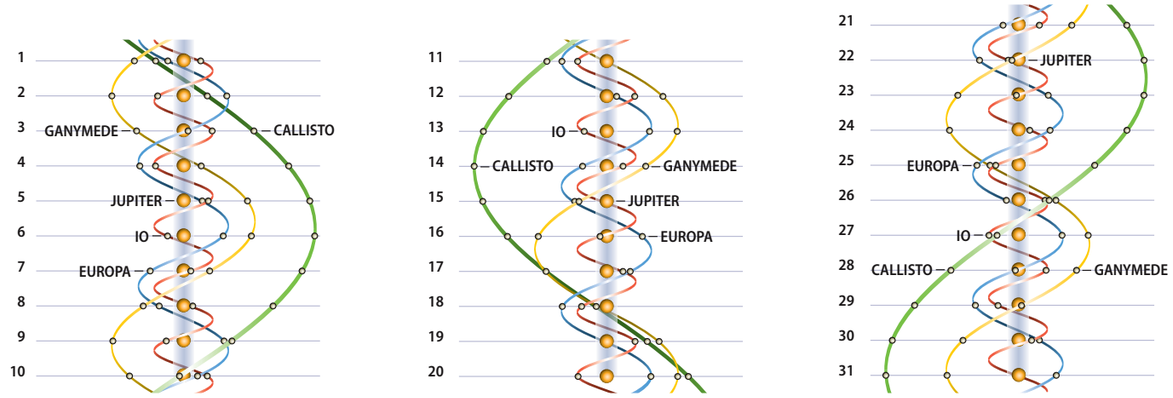
To locate the Moon in the sky, draw a line from the phase shown for the day straight up to the curved blue line.
Note: Moons vary in size due to distance from Earth and are shown in 0h Universal Time.



PLANETS	MERCURY	MERCURY	VENUS	MARS	CERES	JUPITER	SATURN	URANUS	NEPTUNE	PLUTO
Date	October 15	October 31	October 15	October 1	October 15	October 15	October 15	October 15	October 15	October 15
Magnitude	0.9	−0.9	−3.9	1.6	8.7	−2.2	1.0	5.8	7.9	14.0
Angular size	8.6"	5.6"	12.7"	3.8"	0.4"	38.1"	16.4"	3.7"	2.3"	0.1"
Illumination	20%	83%	83%	99%	97%	99%	100%	100%	100%	100%
Distance (AU) from Earth	0.780	1.192	1.309	2.481	2.934	5.174	10.142	19.251	29.532	31.914
Distance (AU) from Sun	0.310	0.354	0.728	1.575	2.572	5.142	9.345	20.098	30.036	31.537
Right ascension (2000.0)	12h28.5m	13h26.2m	15h31.0m	13h43.3m	9h49.4m	19h03.1m	11h14.0m	23h22.1m	21h35.7m	17h54.6m
Declination (2000.0)	−2°26'	−6°54'	−19°56'	−10°29'	19°54'	−22°59'	6°50'	−4°57'	−14°42'	−17°30'

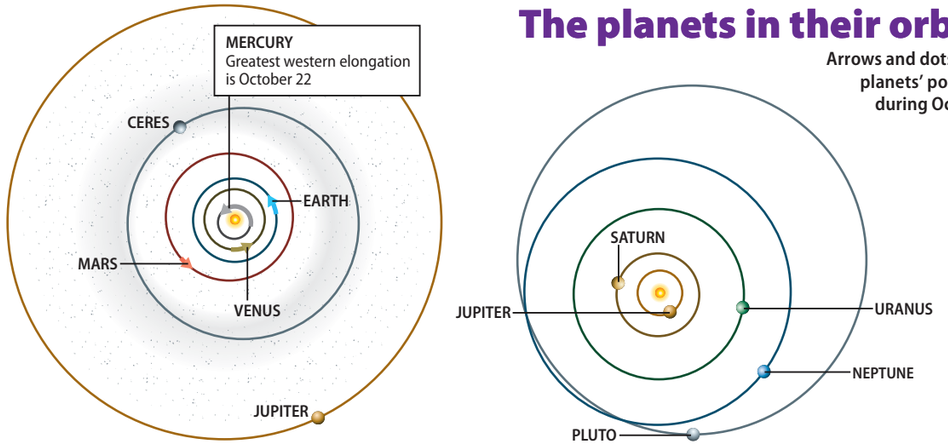
Jupiter's moons

Dots display positions of Galilean satellites at 10 P.M. EDT on the date shown.
South is at the top to match the view through a telescope.



The planets in their orbits

Arrows and dots show planets' positions during October.



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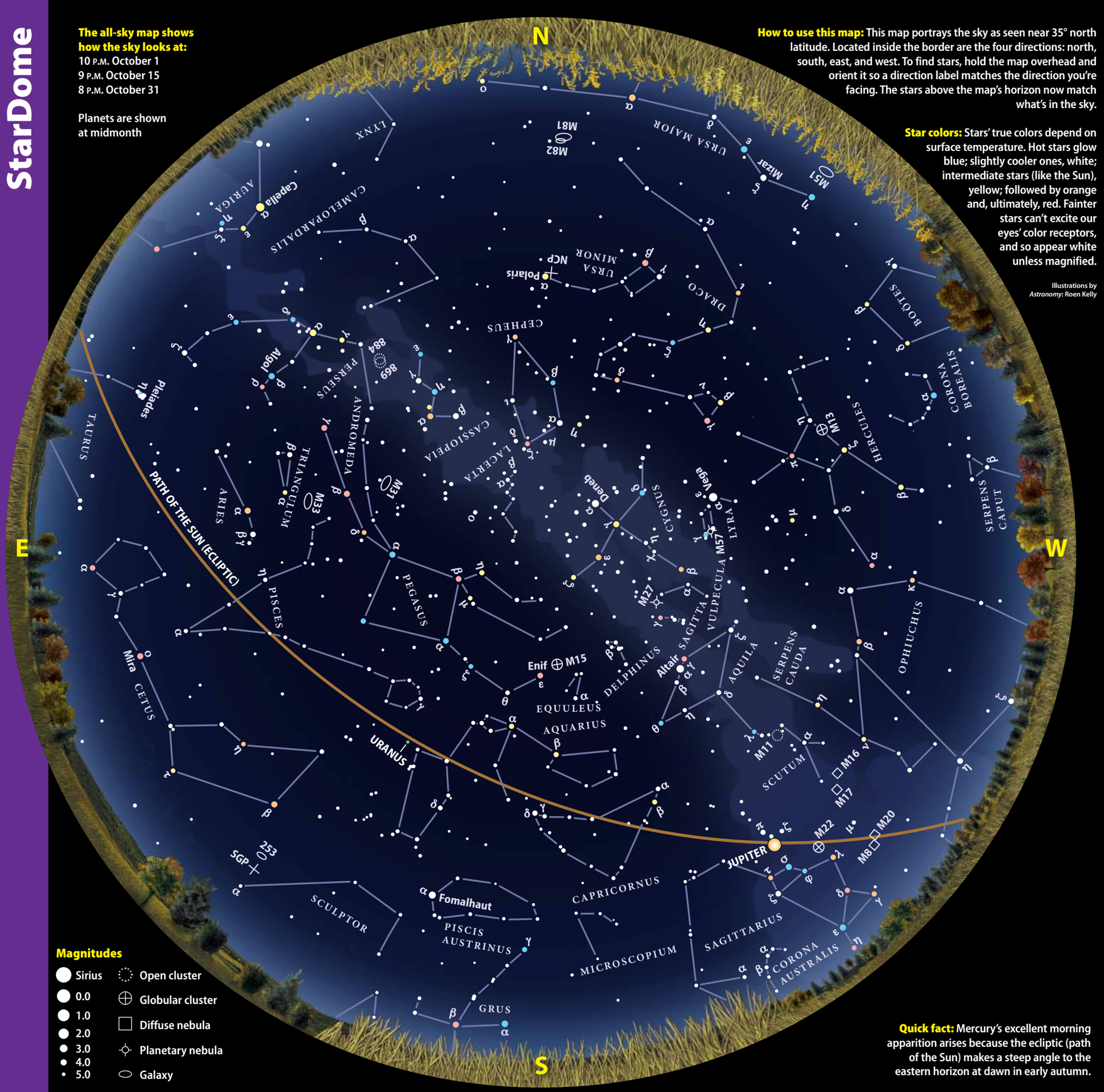


Quick fact: Mercury's excellent morning apparition arises because the ecliptic (path of the Sun) makes a steep angle to the eastern horizon at dawn in early autumn.

October 08

Note: Moon phases in the calendar vary in size due to distance from Earth and are shown at 0h Universal Time.

SUN.	MON.	TUES.	WED.	THURS.	FRI.	SAT.
			1	2	3	4
5	6	7	8	9	10	11
12	13	14	15	16	17	18
19	20	21	22	23	24	25
26	27	28	29	30	31	

Calendar of events

1 The Moon passes 5° south of Venus, 10 P.M. EDT

4 The Moon passes 0.1° south of Antares, 7 A.M. EDT

5 The Moon is at apogee (251,482 miles from Earth), 6:34 A.M. EDT

6 Mercury is in inferior conjunction, 5 P.M. EDT

7 The Moon passes 2° south of Jupiter, 3 A.M. EDT

First Quarter Moon occurs at 5:04 A.M. EDT

10 The Moon passes 0.9° north of Neptune, 6 A.M. EDT

12 The Moon passes 4° north of Uranus, noon EDT

14 Full Moon occurs at 4:02 P.M. EDT

17 The Moon is at perigee (226,069 miles from Earth), 2:09 A.M. EDT

21 Orionid meteor shower peaks

Last Quarter Moon occurs at 7:55 A.M. EDT

22 Mercury is at greatest western elongation (18°), 6 A.M. EDT

Special observing date

22 Mercury puts on its best predawn show of 2008.

25 The Moon passes 5° south of Saturn, 4 A.M. EDT

26 Venus passes 3° north of Antares, 9 A.M. EDT

27 The Moon passes 7° south of Mercury, 2 P.M. EDT

28 New Moon occurs at 7:14 P.M. EDT

29 Asteroid Vesta is at opposition, 10 P.M. EDT

30 Mercury passes 4° north of Spica, 4 P.M. EDT

31 The Moon passes 0.06° north of Antares, 2 P.M. EDT

For definitions of terms, log onto www.Astronomy.com/glossary.

Astronomy magazine

— *Continued from page 40*

and flat western horizon. Mars glows dimly, at magnitude 1.6, and will be tough to see in twilight. Mars and the Moon set just 45 minutes after the Sun.

The Moon returns to Venus' vicinity October 31. This time, Earth's satellite will be easier to see because it sets an hour and a half after the Sun. During the course of the month, the Moon and Venus shift position relative to the starry background. On the 31st, the Moon stands 2.5° to the left of Antares and 5° below Venus. The tight group will make a fine sight Halloween night.

Although **Jupiter** joins Venus in the evening sky, they aren't close. In early October, they lie more than 60° apart, a distance that drops to 30° by month's end. Shining at magnitude –2.2, Jupiter pales in comparison with Venus, although the giant planet still beats every star.

Jupiter lies in Sagittarius, northeast of the Teapot asterism. Look for a First Quarter Moon below Jupiter the evening of October 6.

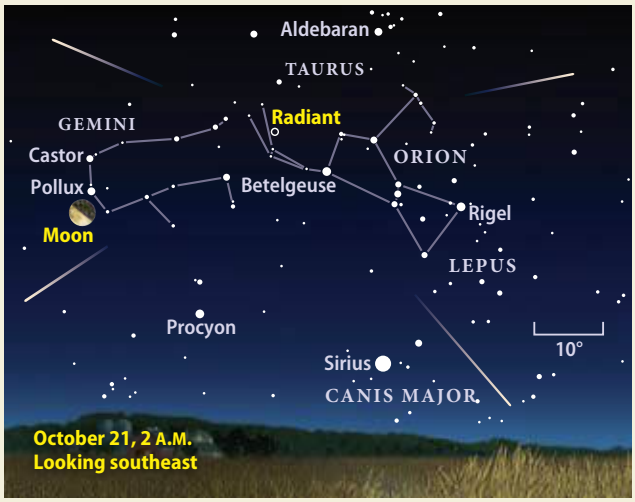
Jupiter's disk spans 38" in mid-October. Although that's down 9" from its July peak, the planet is still big enough to show detail through any telescope. The atmosphere's dynamic cloud belts are a treat. Look for two dark belts arrayed on either side of a brighter equatorial zone.

If you were to draw a line from the Sun to Earth, then continue it on to Jupiter, the angle formed would be 90° October 6. Astronomers call this geometrical position eastern quadrature. For backyard observers, this is a great time to watch the four bright Galilean moons as they emerge from behind Jupiter.

The planet's huge shadow now extends as far east of the planet as it can. The two inner Galilean moons, Io and Europa, remain in the shadow (and thus invisible) for more than an hour after their

Martin Ratcliffe *provides professional planetarium development for Sky-Skan Inc.* **Alister Ling** *is a meteorologist for Environment Canada.*

Meteor watch



Orionid meteors will rain down October 21 under the watch of a Last Quarter Moon. Expect to see roughly 10 meteors from this shower per hour after midnight. *Astronomy*: Roen Kelly

Hunting for meteors

A Last Quarter Moon hinders observations of this year's Orionid meteor shower. Still, this annual shower will be worth a look. First, the Orionids tend to produce bright, swift meteors . Second, the shower may produce more meteors than usual. It exhibited strong activity in 2006, with rates 3 times higher than normal, and some astronomers suspect enhanced activity this year as well.

The Orionids peak before dawn October 21. Observers with excellent sky conditions can expect to see perhaps 10 meteors per hour. The Orionid shower remains a popular event with backyard observers because the nights at this time of year aren't too cold and, even without meteors, the winter sky looks spectacular on display in the autumn morning.

Rising **moon**

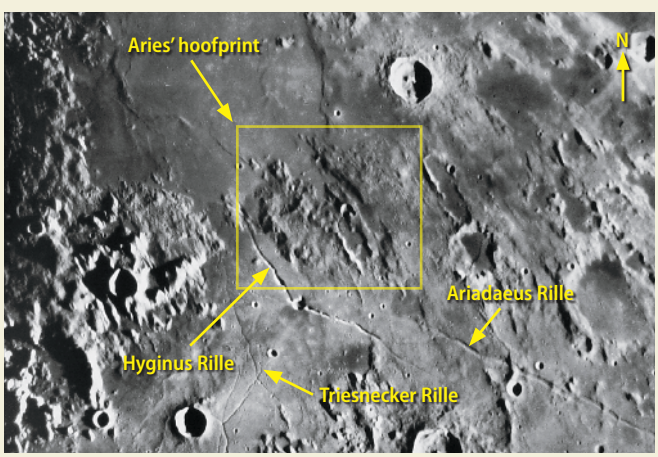
Hoofing it across the ditch

Aries the Ram certainly never stepped on the Moon, but it's fun to imagine that it left a large hoofprint on the lunar surface. By the evening of October 6, the Sun has risen over the fascinating Hyginus, Triesnecker, and Ariadaeus rille complexes. Yet, one thing that catches the eye in this area just north of the lunar equator is the delightful "Aries' hoofprint" feature. The combination of brightly lit mountains and two deep channels of dark lava create this striking play of light and shade.

It's easy to understand why lunar maps don't label this feature — physically, it's a jumble of mountains left over from the giant Imbrium impact, with a channel of large, dark plains on either side.

Lunar scientists focus with good reason on the fascinating Hyginus Rille because it almost surely formed from volcanic activity long ago. But at low power with the whole lunar disk in view, the Aries' hoofprint stands out.

Hyginus Crater is a huge collapse pit, the biggest in a chain of smaller pits that sculpt the edges of a long-ago lava channel. The crater spans 6.6 miles and has walls more than 2,000 feet high. It stands out nicely as the Sun rises because one wall lies in bright sunlight while the other remains in shadow.



Aries' hoofprint makes a tempting target the evening of October 6. Look for it just north of a better known complex of rilles. *Consolidated Lunar Atlas*/UA/LPL

Within just 24 hours, the Aries' hoofprint and the Hyginus Rille become mere echoes of their sunrise magnificence. By October 8, they'll have gone into hiding under the Sun's increasing glare.

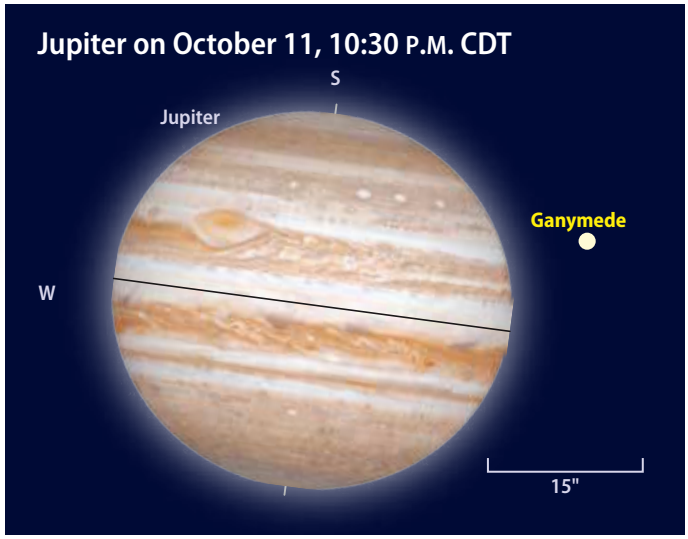
When to view **the planets**

EVENING SKY	MIDNIGHT	MORNING SKY
Venus (southwest)	Uranus (southwest)	Mercury (east)
Mars (west)		Saturn (east)
Jupiter (south)		
Uranus (southeast)		

orbital motions bring them out from behind the planet's eastern limb.

Ganymede and Callisto, however, orbit far enough from Jupiter that they reappear after the planet occults them and before they plunge into the shadow. Such events can occur only within a few months of quadrature. Unfortunately, they don't happen often when both the sky is dark and the planet is visible, so you have to seek them out.

The best-timed event this month for most North American observers comes October 11. Those located in the central and western parts of the continent can watch Ganymede through an entire sequence. The solar system's largest moon reappears from behind Jupiter at 9:42 P.M. CDT and enters Jupiter's shadow 2 hours later, at 11:40 P.M. CDT. (For East Coast observers, Jupiter sets before the eclipse begins.)



Ganymede appears for about 2 hours October 11, between the time Jupiter occults and eclipses the moon. *Astronomy*: Roen Kelly

Neptune glows at magnitude 7.9, so it's easy to pick out through binoculars. You'll find the planet 2.2° northwest of the 4th-magnitude star Gamma (γ) Capricorni. Neptune lies due east of a line of three 5th- and 6th-magnitude stars. All these objects will appear in the same field of view as Gamma through 7x50 binoculars. Point a telescope at Neptune, and you'll see a blue-gray disk measuring a paltry 2.3" across.

Neptune's inner neighbor, **Uranus**, stays visible most of the night. It lies in northeastern Aquarius, some 2° east-northeast of 4th-magnitude Phi (ϕ) Aquarii. Although the planet's 6th-magnitude glow makes it bright enough to see with the naked eye from a dark site, binoculars make the task much easier. Uranus is the brightest object near Phi in a typical binocular field. A telescope shows Uranus as a blue-green disk 3.7" across.

Early risers will welcome the return of **Saturn** following last month's solar conjunction. The prominent morning object rises 2 hours before

Comet search

An evening escapade

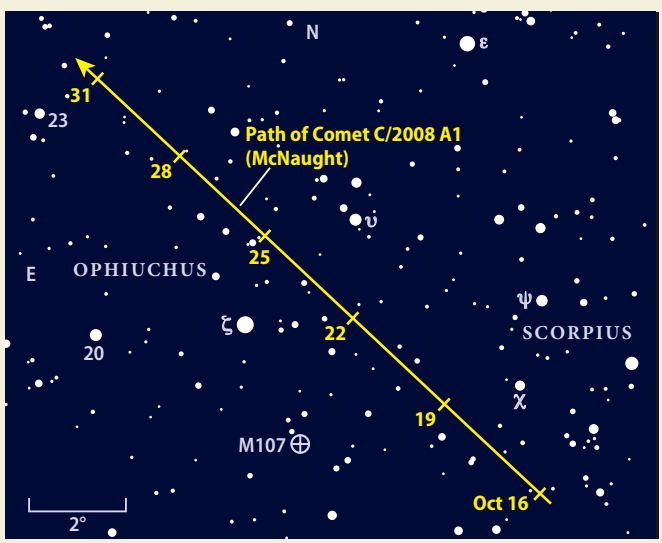
A couple of hours after the Sun sets in late October is the perfect time to hunt for Comet C/2008 A1 (McNaught). October evenings often offer a mild, dry, and transparent sky. This provides a dark background for observing low-contrast details in comfort, before you get chilled and your optics get covered in dew.

Comet C/2008 A1 lies among the background stars of Ophiuchus the Serpent Bearer. To view this elongated fuzzball, which should glow around 8th or 9th magnitude if predictions hold true, you'll want to escape from city sky glow and interfering moonlight.

As a result, the observing window for this comet cracks open October 18, when there's an hour between the end of twilight and moonrise. The window widens each night until November 2, when the Moon returns to the evening sky.

It always pays to observe a comet with a variety of eyepieces. While one magnification may give you the best overall view, the extremes can be revealing. If you sweep slowly back and forth at low power, you'll probably see a weak tail pointing to the northeast. At high power, the nearly stellar "false nucleus" may poke through the bright inner coma.

Take a few minutes to compare the comet with the nearby globular star cluster M107. Which shows more detail? Do they both brighten toward the center in the same way? Instead of checking a box on your observing list for tonight, you'll find that longer looks can be more satisfying.



Comet C/2008 A1 (McNaught) passes Ophiuchus during the latter half of October, near the globular cluster M107. The comet should glow around 8th magnitude. Astronomy: Roen Kelly

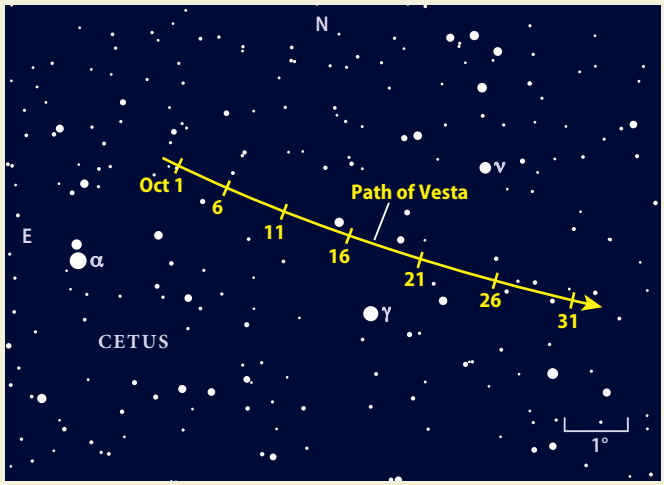
Although Comet C/2008 A1 has started to fade, it climbs higher in the sky for Northern Hemisphere observers. It will remain well-placed for viewing through November.

Vesta's whale of a good show

The brightest of thousands of known asteroids, Asteroid 4 Vesta, reaches its peak in October. The asteroid comes to opposition October 29, when it lies opposite the Sun and remains visible all night. At magnitude 6.4, it's then bright enough to see easily through binoculars from the city. Wait to hunt it down until late evening, when Vesta's host constellation, Cetus the Whale, has climbed high in the east.

To track Vesta, start at ruddy Aldebaran in Taurus the Bull. Then follow the point of the V-shaped Hyades star cluster to the west until you reach 2.5-magnitude Alpha (α) Ceti. The chart here shows an area a bit wider than a typical binocular field. With only a handful of background stars brighter than this space rock, it will be easy to track. The exception comes at midmonth, when a nearly Full Moon crosses the region.

Astronomer Heinrich Olbers discovered Vesta in 1807. It was the fourth such object found between the orbits of Mars and Jupiter. Vesta spans some 300 miles, making it one of the largest main-belt asteroids. It appears brighter than the larger ones because its surface reflects more sunlight.



Asteroid Vesta reaches the peak of its 2008 apparition in late October. You can spot the 6th-magnitude object easily through binoculars among the stars of Cetus. *Astronomy:* Roen Kelly

sunrise in early October and 4 hours before the Sun by month's close. Saturn shines marginally brighter than Regulus, the brightest star in Saturn's host constellation, Leo the Lion. The planet currently lies south of the Lion's hindquarters.

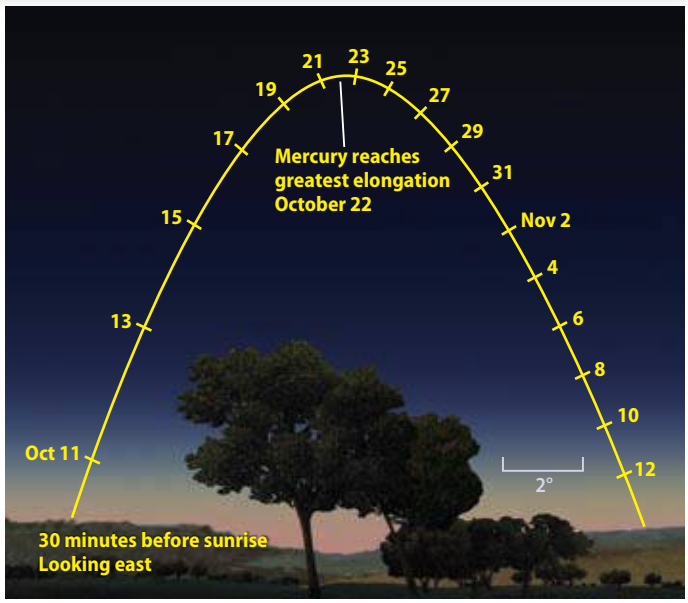
Despite pulling closer to Earth during October, Saturn fades slightly (from magnitude 1.0 to 1.1). Blame it on Saturn's rings. The rings typically reflect more light than the planet's disk. But the angle of the rings to our line of sight is steadily decreasing. During October, the tilt shrinks from 3.6° to 2.1°.

Next year, we will cross the ring plane and view them (or not) edge-on. The nearly edge-on rings allows observers to see most of the planet's disk. In mid-October, it spans 16.4" across the equator and 14.8" through the poles.

On October 6, **Mercury** passes between the Sun and Earth in a configuration known as inferior conjunction. This starts the final chapter in our night-sky saga. That same day, NASA's MESSENGER spacecraft flies past the innermost planet for the second time this year. After inferior conjunction, Mercury moves west of the Sun and becomes visible in the morning sky within 10 days. By that time, hundreds of MESSENGER images should have been returned to Earth, many showing regions of the planet never seen before.

On October 16, Mercury lies 8° above the eastern horizon 30 minutes before sunrise and shines brightly at magnitude 0.5. The key to good views of Mercury is its angular distance from the Sun. All else being equal, the greater this distance, the sooner the planet rises before our star (or sets later, in the case of evening apparitions).

Mercury reaches greatest elongation October 22, when it stands 18° west of the Sun. This isn't the largest angular distance Mercury can achieve. The planet passed through perihelion, the closest point in its orbital path around the Sun, just 5 days earlier. Nevertheless, Mercury stands 5° high in the east an hour before sunrise October 22,



Mercury appears bright before dawn during the last half of October. By month's end, the innermost planet shines as bright as Sirius. *Astronomy:* Roen Kelly

and climbs another 6° in the next 30 minutes. It shines a full magnitude brighter than it did a week before, and will be easy to find.

On October 16, a telescope reveals the inner planet's 8"-diameter disk, which appears 27 percent lit. As the planet heads toward greatest western elongation, its disk shrinks and the illumination increases. By the 22nd, the globe appears 7" across and 55 percent sunlit.

Mercury lingers through October's final week, when it will be easiest to see as it continues to brighten.

On October 31, Mercury shines at magnitude –0.9. It lies 8° above the eastern horizon 30 minutes before sunrise. It also lies 4° north of Spica, the brightest star in Virgo the Maiden, that morning. Through a telescope, Mercury's disk is then 83 percent illuminated and 6" across.

Calling all space probes

These spacecraft monitor the Sun, study Saturn, and explore interplanetary — and soon, interstellar — space. **by Francis Reddy; illustration by Roen Kelly**

Today, space probes course throughout the solar system, from the innermost planet to beyond Pluto. This plot shows all lunar or planetary orbiters and interplanetary spacecraft still returning data as of June 1, 2008.

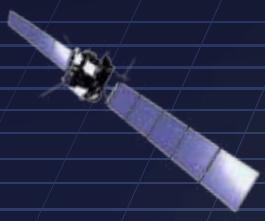
NASA's oldest probe, the solar-orbiting Pioneer 6, turns 43 this year, but isn't shown. According to Pioneer Project Manager Larry Lasher, this ancient spacecraft probably still functions, but there's no longer any scientific value in communicating with it.

Four spacecraft — ACE, SOHO, Wind, and Ulysses — now study the Sun, while four others — Rosetta, Stardust, Deep Impact, and Dawn — are en route to study comets and asteroids. Two planetary missions, MESSENGER and New Horizons, are still cruising to their targets.

Voyagers 1 and 2 are headed to interstellar space after giving scientists a whirlwind tour of the outer planetary system. Both spacecraft have entered the outermost region of a bubble carved in space by the Sun's outflow, called the solar wind. Scientists estimate the craft have enough electrical power to function until 2020. By then, they may have crossed into true interstellar space.

Voyager 1 is not only the farthest spacecraft, but also the fastest. Even so, it will not cruise within 2 light-years of another star for 40,000 years.

Francis Reddy *is a senior editor of* Astronomy.



Rosetta
Launched: March 2, 2004
Nation: European collaboration
Mission: Rendezvous and orbit Comet 67P/Churyumov-Gerasimenko
Distance from Sun: 165 million miles (265 million km)

Stardust
Launched: February 7, 1999
Nation: United States
Mission: Flyby of Comet 81P/Wild (2004), return dust samples to Earth (2006), flyby of Comet 9P/Tempel (2011)
Distance from Sun: 157 million miles (253 million km)

Ulysses
Launched: October 6, 1990
Nation: United States
Mission: High-inclination solar studies
Distance from Sun: 278 million miles (447 million km)

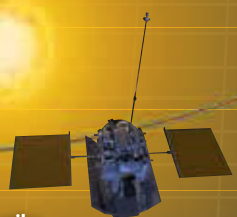
Dawn
Launched: December 18, 2007
Nation: United States
Mission: Exploration of asteroids Vesta (2011) and Ceres (2015)
Distance from Sun: 152 million miles (245 million km)

Mercury
Distance from Sun: 43 million miles (69 million km)

Venus Express
Launched: November 9, 2005
Nation: European collaboration
Mission: Detailed study of Venus' atmosphere and clouds

Deep Impact
Launched: January 12, 2005
Nation: United States
Mission: July 2005 flyby of Comet 9P/Tempel; en route to 103P/Hartley 2 (October 2010)
Distance from Sun: 92 million miles (148 million km)

Venus
Distance from Sun: 67 million miles (108 million km)



MESSENGER
Launched: August 3, 2004
Nation: United States
Mission: Mercury flyby (2008, 2009) and orbiter (2011)
Distance from Sun: 30 million miles (48 million km)

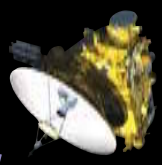
The farthest working spacecraft

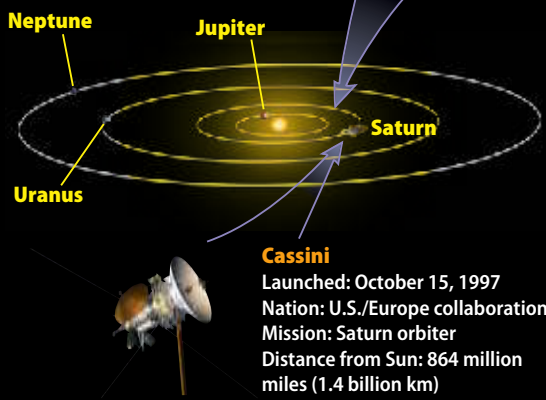
Voyager 1
Launched: September 5, 1977
Nation: United States
Mission: Interstellar probe following flybys of Jupiter and Saturn
Distance from Sun: 9.9 billion miles (15.9 billion km)

Jupiter
Distance from Sun: 482 million miles (776 million km)

Voyager 2
Launched: August 20, 1977
Nation: United States
Mission: Interstellar probe following flybys of Jupiter, Saturn, Uranus, and Neptune
Distance from Sun: 7.9 billion miles (12.9 billion kilometers)

New Horizons
Launched: January 19, 2006
Nation: United States
Mission: Pluto flyby in 2015
Distance from Sun: 919 million miles (1.5 billion km)





Cassini
Launched: October 15, 1997
Nation: U.S./Europe collaboration
Mission: Saturn orbiter
Distance from Sun: 864 million miles (1.4 billion km)

Probes near Earth

Solar and Heliospheric Observatory (SOHO)
Launched: December 2, 1995
Nation: U.S./Europe collaboration
Mission: Solar imaging

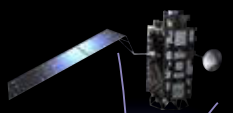
Wind
Launched: November 1, 1994
Nation: United States
Mission: Monitor changes in the solar wind and the interplanetary magnetic field

Sun-Earth L1
Distance from Sun: 91.9 million miles (148 million km)

L1

Advanced Composition Explorer (ACE)
Launched: August 25, 1997
Nation: United States
Mission: Monitor changes in the solar wind and the interplanetary magnetic field

Kaguya (SELENE)
Launched: September 13, 2007
Nation: Japan
Mission: Lunar mapping

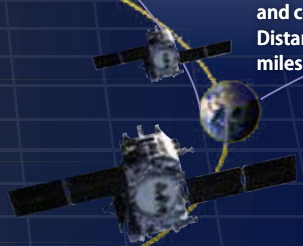


Chang'e 1
Launched: October 24, 2007
Nation: China
Mission: Lunar mapping

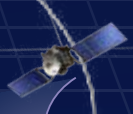
Moon
Distance from Sun: 94.1 million miles (151.4 million km)

Earth
Distance from Sun: 94.3 million miles (151.7 million km)

Solar TErrestrial RElations Observatory (STEREO) A
Launched: October 25, 2006
Nation: United States
Mission: 3-D studies of the Sun and coronal mass ejections
Distance from Sun: 89.2 million miles (144 million km)

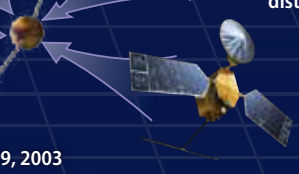


Mars Express
Launched: June 2, 2003
Nation: European collaboration
Mission: High-resolution imaging



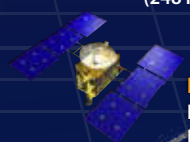
Mars Odyssey
Launched: April 7, 2001
Nation: United States
Mission: Mapping the distribution of surface minerals

Mars
Distance from Sun: 154 million miles (248 million km)

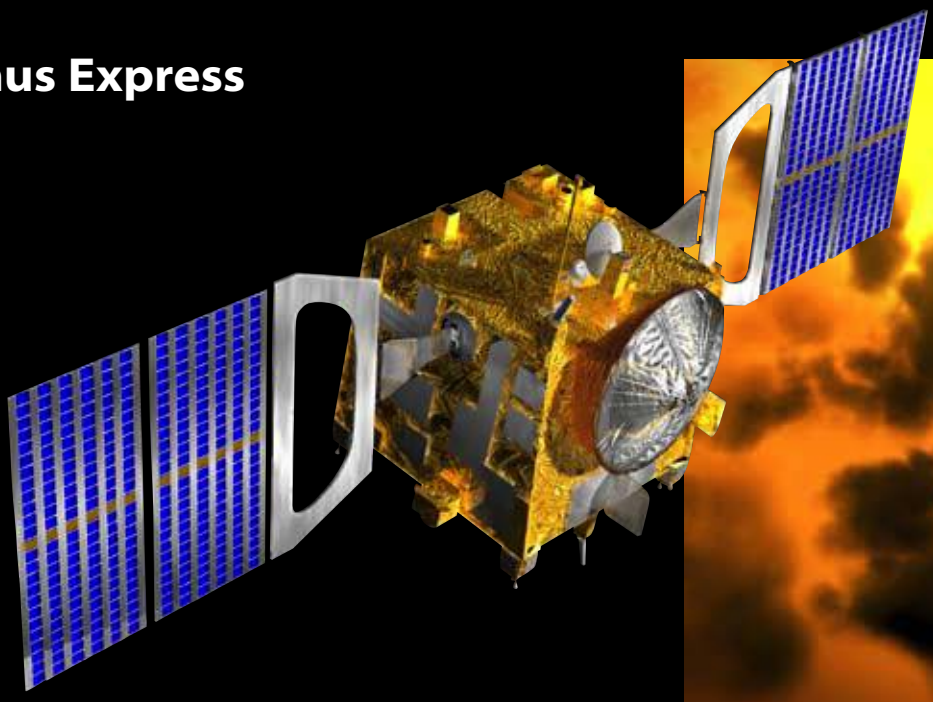


Mars Reconnaissance Orbiter
Launched: August 12, 2005
Nation: United States
Mission: High-resolution imaging

STEREO B
Launched: October 25, 2006
Nation: United States
Mission: 3-D studies of the Sun and coronal mass ejections
Distance from Sun: 97.6 million miles (157 million km)



Hayabusa
Launched: May 9, 2003
Nation: Japan
Mission: First surface operations on an asteroid (Itokawa, 2005)
Distance from Sun: 149 million miles (239 million km)



Taking Venus by

Since the dawn of the Space Age, humans have launched more than 300 satellites to study Earth's atmosphere and weather. Some stare down from geosynchronous orbit, continuously viewing an entire hemisphere of our home world's atmosphere. Others skim along in low Earth orbit, where they track daily weather changes. And still others monitor climate, measuring long-term changes in Earth's cloud cover, rain patterns, and temperature. Scientists have been able to study almost every aspect of Earth's atmosphere and climate.

The story is different, however, with Venus. Sitting tens of millions of miles away, it is often called Earth's sister world. Venus is about the same size as our planet and has its own complex and dense atmosphere. Yet despite its nearness and similarity, scientists had never put a dedicated weather satellite into orbit around it.

That all changed 2 years ago. The European Space Agency's Venus Express spacecraft began orbiting Venus in April 2006 and has been sending back a steady stream of data ever since. The probe has given scientists their first detailed long-term view of Venus' atmosphere and climate.

"Venus Express is allowing us to get a more mature, sophisticated, in-depth picture of what's really going on," says David

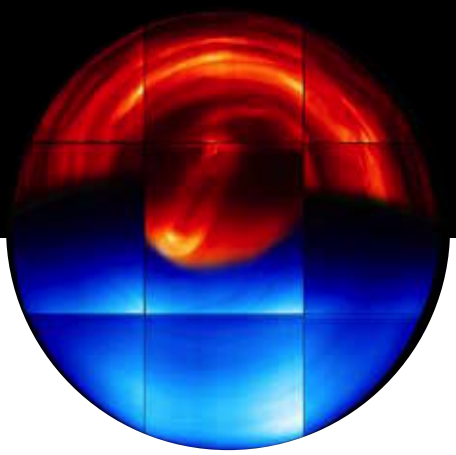
A frequent contributor to Astronomy, **Robert Zimmerman***'s newest book,* The Universe in a Mirror: The Saga of the Hubble Space Telescope and the Visionaries Who Built It, *has just been released by Princeton University Press.*

Lightning flashes in Venus' thick, hot, and cloudy atmosphere (above). Venus Express (top left) — the first weather satellite sent to Earth's enigmatic sister world — detected conclusive evidence for lightning in the planet's atmosphere. Artist's concept: ESA/Christophe Carreau; Spacecraft: ESA

storm

Europe's new spacecraft is revealing the composition, circulation patterns, and intense lightning of our sister world's atmosphere.

by Robert Zimmerman



Venus' entire southern hemisphere shows up in this mosaic. Ultraviolet images make up the day-side hemisphere (in blue at bottom), while infrared images reveal the night side (in red at top). The central panel shows the double vortex at the planet's south pole. ESA/VIRTIS-VenusX/IASF-INAF/Obs. de Paris (R. Hueso, Univ. Bilbao)

A Y-shaped cloud pattern in the equatorial regions showed up in this image taken by the Mariner 10 spacecraft when it flew past Venus in 1974. NASA

Grinspoon of the University of Colorado, an interdisciplinary scientist with the Venus Express mission. "Seeing the patterns and the long-term changes in Venus' climate is going to allow us to do comparative planetology, which will ultimately shed light back on Earth's climate and how it works and changes."

So far, the results have excited and surprised scientists. In May, researchers announced the discovery of hydroxyl in Venus' atmosphere. This highly reactive molecule, which comprises one atom each of oxygen and hydrogen, plays a key role in purging pollutants from Earth's atmosphere. It also tracks ozone abundance. Scientists now think it performs the same function on Venus.

"Venus Express has already shown us that Venus is much more earthlike than once thought," says Giuseppe Piccioni of IASF-INAF in Rome, a principal investigator on the spacecraft's Visual and Infrared Thermal Imaging Spectrometer. "The detection of hydroxyl brings the planets a step closer."

A Cold War destination

Scientists haven't always shared this view. Fifty years ago, we knew practically nothing about the conditions on Venus. Its all-encompassing atmosphere of thick clouds hid the planet's surface from our gaze. Science fiction writers and scientists alike theorized that Venus' clouds would make it a wet world, drenched by incessant rains and covered either with vast oceans or dense, damp jungles.

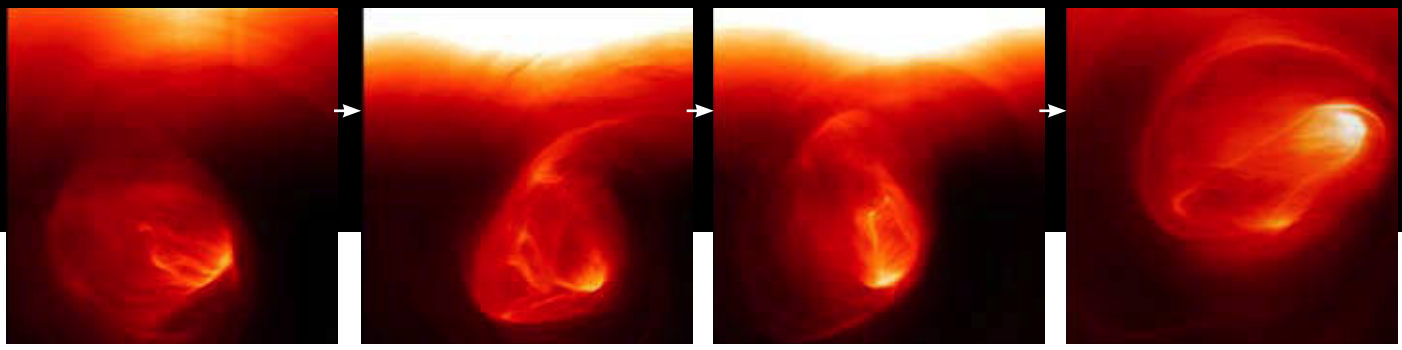
Yet no one knew for sure. Venus remained a cipher — bright and beautiful, but an impenetrable planetary mystery.

Then came the space race, and Venus' mask slowly dissolved. In December 1962, the U.S. Mariner 2 spacecraft flew within 21,580 miles (34,730 kilometers) of Venus and showed that its atmosphere was nothing like Earth's. Temperatures at the surface appeared to exceed a blistering 800° Fahrenheit (425° Celsius). No deep oceans or dank jungles could exist there. The spacecraft's data also proved that Venus rotates slowly in a retrograde direction. The Sun rises in the west and sets in the east, with each sluggish day lasting 117 Earth days.

Later probes from the United States and the Soviet Union showed Venus to be even stranger and more hostile. Of the 13 Soviet Venera spacecraft that successfully reached Venus from 1967 to 1983, eight managed to land and survive long enough on the surface to beam back images, wind conditions, and atmospheric data, and analyze the ground's mineral content.

These probes proved that the bottom of Venus' atmosphere is so dense that all is essentially still, with wind speeds rarely faster than a tepid 2 mph (3 km/h). The air pressure is bone-crushingly heavy, almost 100 times Earth's. The temperature reaches a brutal 900° F (480° C), hot enough to melt lead. The atmosphere there exists under so much pressure that, in many ways, it behaves like a transparent, molasseslike liquid.

Conditions in the upper venusian atmosphere proved as alien as those at the surface. The Soviet probes, along with two American orbiters, Pioneer Venus Orbiter (1978–92) and Magellan (1990–94), showed that the clouds forever shrouding Venus' surface consist not of water, but of sulfuric acid. Acidic



The south polar vortex can change shape rapidly. Venus Express took this four-image infrared sequence during three orbits in August 2007.
ESA/VIRTIS-VenusX/INAF-IASF/Obs. de Paris-LESIA (A. Cardesin Moinelo, IASF-INAF)

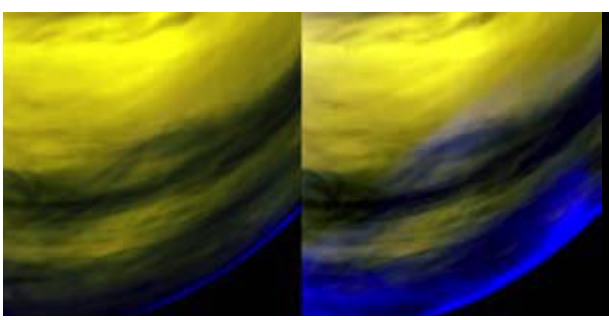
droplets rain down from the top of the cloud deck at an altitude of some 40 miles (65 km). Because Venus' atmosphere is so hot, this sulfuric acid rain never reaches the ground. At about 30 miles (50 km) altitude, the temperature reaches 200° F (95° C), hot enough to evaporate the acidic rain back into a gas, which subsequently rises upward to repeat the cycle.

Strange discoveries just kept coming. Pioneer Venus Orbiter found a gigantic vortex at the planet's north pole that resembles a colossal hurricane. Although scientists had theorized such a vortex would exist, they were taken aback to find a bizarre "double eye" at the center of the storm. The vortex rotates about once every 3 days and is slightly offset from the north pole. Unfortunately, the orbiter could not view the planet's south pole to see if a similar structure existed there.

The various probes of the 1970s, 1980s, and 1990s also turned up three major circulation patterns in Venus' atmosphere. One flow turns up at altitudes above 75 miles (120 km). There, the midday Sun causes the atmosphere to warm, rise, and then flow nightward, where it sinks and flows back toward the day side.

The second flow is what scientists call a Hadley cell; it exists at altitudes below 40 miles (65 km). Warmer regions at the equator cause air to rise and flow toward the poles, where it sinks and flows back toward the equator. Venus' two Hadley cells equalize the surface temperature at all latitudes.

The third flow is a gigantic jetstream that blows from east to west at speeds of about 225 mph (360 km/h) and circles the planet every 4 days. This flow lies about 40 miles (65 km) up, at the top of the cloud deck. This "super-rotation," as scientists call it, flows 60 times faster than the planet rotates. The movement shows up in ultraviolet wavelengths at all latitudes below 60°. It causes the planet's clouds to form a huge, rotating "Y" turned on its side and centered over the equator.



Blue light at night arises from oxygen airglow. Oxygen atoms liberated by solar radiation migrate to Venus' night side, where they sink and then combine into molecules. This recombination gives off the infrared light seen here.
ESA/VIRTIS/INAF-IASF/Obs. de Paris-LESIA

The "double-eye" structure of the north polar vortex shows up in intricate detail in this artist's concept. This vortex rotates around the pole in about 3 days, slightly slower than the south polar vortex. ESA/AOES Medialab

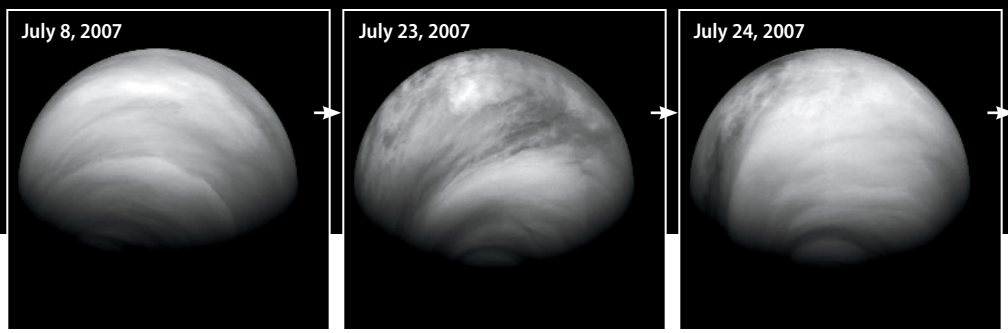
By the mid-1990s, scientists had a good snapshot of Venus. Nonetheless, this first wave of exploration left many questions unanswered. The spacecraft did not operate long enough or have enough resolution to completely characterize the complex atmosphere, its circulation patterns, composition, or weather.

A new arrival

That's where things stood in October 1994, when mission controllers sent Magellan to a fiery death in Venus' atmosphere. For the next 11 years, no dedicated Venus probes visited Earth's sister planet. Scientists had to rely on ground-based telescopes and a few brief flybys made by spacecraft designed to study other planets.

This dearth of new data ended in 2006. The European Space Agency (ESA) launched Venus Express November 9, 2005, and it arrived 5 months later. The craft carries seven instruments able to take images and spectra from ultraviolet through infrared wavelengths, making it the first true Venus weather satellite.

ESA plans to keep Venus Express going until at least May 2009, so it will



Light and dark clouds in Venus' southern hemisphere can show dramatic changes in just a few days. Scientists think that sulfuric acid droplets produce the bright haze, but don't know what causes the darker regions. ESA/MPS/DLR/IDA

be able to observe changes in the planet's atmosphere over 5 Venus years. The spacecraft orbits the planet on a high-inclination, eccentric path that gives it a wide-angle view of Venus' south pole and a close-up view of the north pole each orbit. Over time, this perspective will allow the spacecraft to build up a detailed picture of Venus' climate.

Almost immediately after it arrived at the planet, Venus Express produced results. The first images of the south pole proved that Venus has "double eyes" rotating above each of its poles. And, while these double hurricanes may not be permanent features, they certainly last a long time. The south pole vortex completes a rotation in approximately 2.5 days, slightly faster than the north pole vortex.

Venus Express also established conclusively that lightning occurs in Venus' atmosphere. Although some previous spacecraft had detected flashes that seemed to mimic lightning, other probes had come up empty. Almost as soon as Venus Express began gathering data, it detected bursts of electromagnetic radiation. They lasted from one-quarter to one-half second, occurred at random moments, and had varying amplitudes, all similar to how lightning behaves in Earth's atmosphere.

Venus Express Project Scientist Håkan Svedhem noted during a November 28, 2007, press conference that lightning on Venus holds significance because it provides "a source of energy input and a catalyst to chemical reactions." This means that Venus' atmosphere is far more active and dynamic than many scientists had expected.

During its initial 2 years in orbit, Venus Express helped create the first detailed maps of the shape and size of Venus' two hemispheric Hadley cells. Surprisingly, the cells turn out to be different than expected. Instead of circulating from the equator all the way to the poles, the poleward flow of both cells seems to die off at about 60° latitude.

At these locations, two relatively cold jetstreams, dubbed "polar collars," encircle both poles at an altitude of about 40 miles (65 km), at the top of the planet-covering cloud deck. The poleward flow of each Hadley cell stops at these collars, then sinks and disappears into Venus' hot, dense atmosphere. Scientists have not yet spotted the deeper return flow toward the equator, but they hope that Venus Express eventually will find and map it.

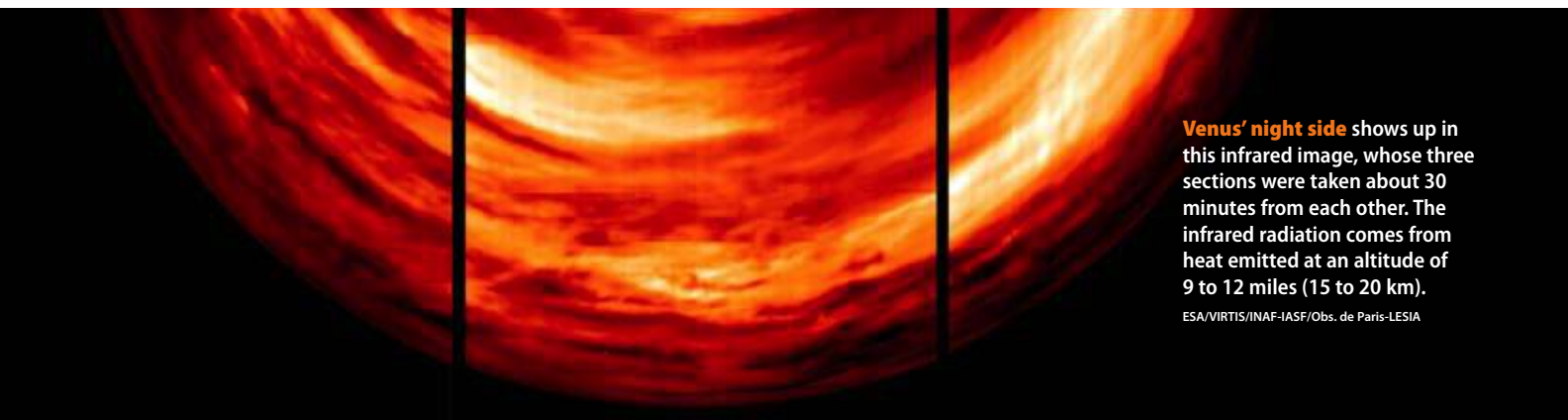
Ultraviolet and infrared images combine in this picture of Venus. Ultraviolet light (upper right) reveals high clouds, while infrared light (lower left) shows lower layers. ESA/VIRTIS and VMC teams

In the polar regions above 60° latitude, where the dipole hurricanes dominate the atmosphere, Venus Express finds the weather to be surprisingly variable and unpredictable. Sometimes in the space of a single Earth day, the entire south polar region gets covered with a dense haze of sulfuric acid droplets. The haze obscures all details to latitudes as low as 35°. A day later, this haze dissipates, and the ever-present dipole hurricane at the pole and the global Y-shaped winds over middle latitudes return to view.

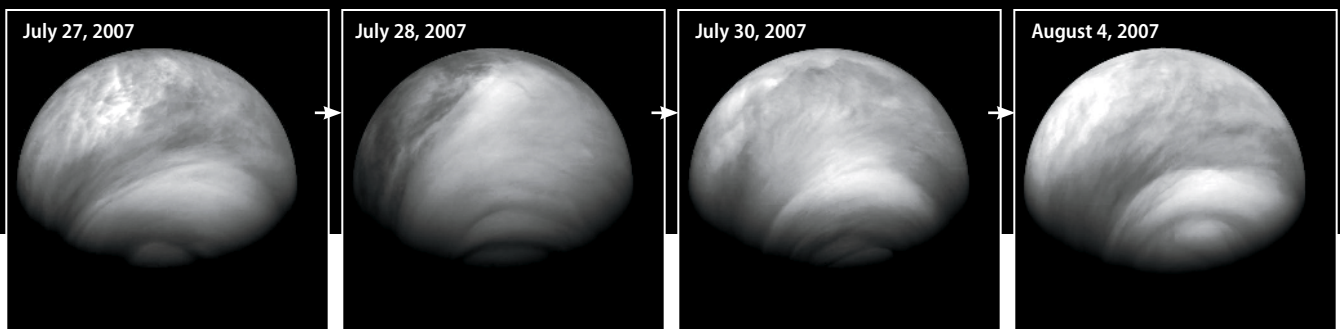
Scientists think that these hazes occur when water droplets in the cloud deck rise enough to be exposed to the Sun's ultraviolet rays. This high-energy radiation breaks the water into hydrogen and oxygen atoms, which then recombine with atmospheric sulfur to form the sulfuric acid haze.

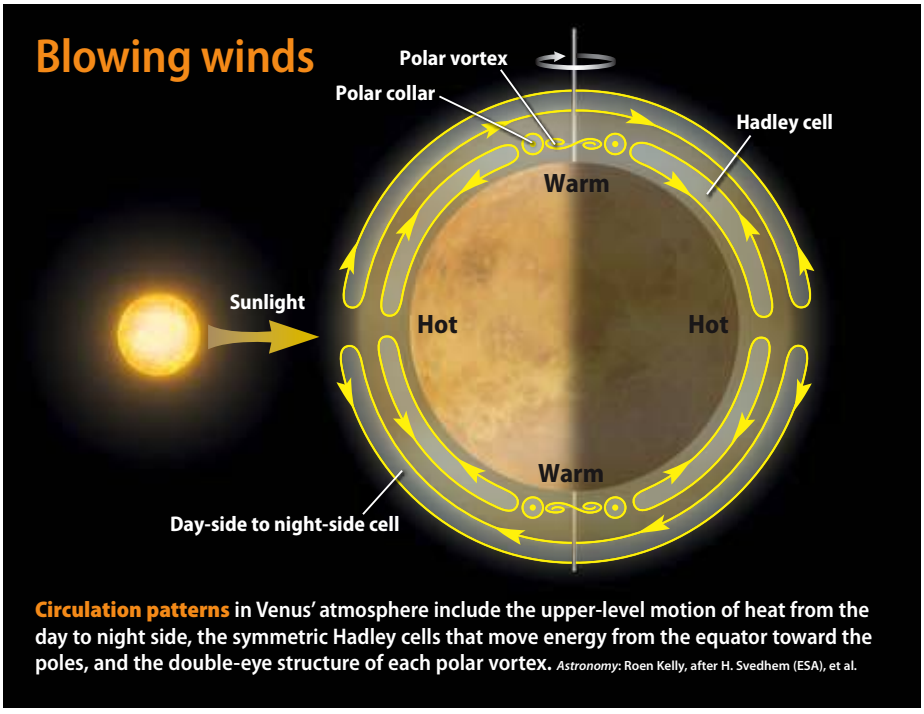
Scientists have yet to work out the details of what causes the water vapor to rise, how it interacts with the Sun's ultraviolet radiation, and what makes the haze go away.

More recently, Venus Express detected rapid changes in the amount of sulfur dioxide in the planet's upper atmosphere. Some scientists see this as evidence of volcanic eruptions, while others



Venus' night side shows up in this infrared image, whose three sections were taken about 30 minutes from each other. The infrared radiation comes from heat emitted at an altitude of 9 to 12 miles (15 to 20 km). ESA/VIRTIS/INAF-IASF/Obs. de Paris-LESIA





Circulation patterns in Venus' atmosphere include the upper-level motion of heat from the day to night side, the symmetric Hadley cells that move energy from the equator toward the poles, and the double-eye structure of each polar vortex. *Astronomy*: Roen Kelly, after H. Svedhem (ESA), et al.

Ultraviolet light highlights both streaky and mottled clouds in Venus' southern hemisphere. In this view, the south pole lies at center left and the equator forms the right-hand limb.

ESA/MPS/DLR-PF/IDA

remain skeptical. The skeptics, however, have yet to come up with a mechanism to explain the high amounts of sulfur dioxide.

On the trail of water

Not all of Venus Express' discoveries have been as eye-catching. Because Venus and Earth formed in approximately the same place in the solar system, scientists have assumed the planets started out with similar chemical compositions. Carbon dioxide makes a good case. Earth has lots of this compound, most of it trapped in the planet's crust. Venus has plenty as well, but most of it lurks as a gas in the atmosphere. Nevertheless, the overall amount of carbon dioxide on both planets appears to be about the same.

But what happened to Venus' water? Earth has lots, while Venus appears to have almost none. What little Venus does possess exists in the atmosphere. Scientists think that Venus' hotter conditions caused its water molecules to break up into hydrogen and oxygen and eventually escape into space.

Observations from Venus Express support this theory. The spacecraft sees streams of hydrogen and oxygen escaping from the planet's atmosphere in a two-to-one ratio — the exact ratio expected if these atoms came from water.

These early discoveries tell only the beginning of the Venus Express story. As the mission unfolds over the next year or more, it will build a picture of Venus' weather and climate. Scientists will monitor the amount of atmospheric sulfur dioxide, for example. Any abrupt increase over a small region will provide evidence of an active volcano. Similarly, as the spacecraft tracks lightning bursts, it will tell us something about the planet's powerful local storms.

Mission scientists also hope Venus Express will answer some long-standing questions about Venus' atmosphere. A key one: What unidentified molecule in the upper atmosphere absorbs ultraviolet light and allows us to see the nearly global Y-shaped clouds? Given time, scientists expect Venus Express to help them figure out what it is.

Venus Express' most important result likely will be its incremental gathering of knowledge. For example, the craft only recently made its first precise measurements of water vapor near the planet's surface, and of hydroxyl, sulfur dioxide, nitric oxide, and other chemicals higher up.

Such observations may not be as flashy as the discovery of an erupting volcano or a lightning burst, but it's the accumulation of such seemingly mundane information that will eventually tell us how Venus' atmosphere functions and how it got to be the way it is. And from that knowledge, we almost certainly will learn something about Earth's atmosphere, and find out how it got to be the way it is.

Ask Astro

Astronomy's experts from around the globe answer your cosmic questions.

Solar storms turned Chicago's sky red

Q: In Chicago, shortly before World War II began, I saw the evening sky turn blood red. What caused this? — **Katherine Krupp,** Mesa, Arizona

A: The crimson glow you saw occurred September 18, 1941. **It was the opening act of one of the greatest auroral displays recorded in the central United States.**

The Sun often erupts large amounts of gas from its outer atmosphere, called the corona. Scientists now call these eruptions "coronal mass ejections," or CMEs, but they were unknown in the 1940s.

A CME hitting Earth creates a geomagnetic storm ("The Sun's biggest blasts," December 2006). Electrons rush into our planet's upper atmosphere, which makes the gases glow as in a neon sign. We see this glowing as an aurora.

The color each gas emits depends both on the molecule and its altitude. The "blood-red" color comes from oxygen atoms between 125 and 310 miles (200 and 500 kilometers) high.

Electrons causing an all-red aurora have relatively low energy and can't penetrate far enough into the atmosphere to make the more familiar green color. So, all-red aurorae occur near the start of a major geomagnetic storm, and only rarely at that.

The solar storm responsible for the glow you saw began September 17 at 10 P.M. CST. The activity intensified between 6 and 9 P.M. CST September 18 — perfectly timed for a spectacular evening display in Chicago. Observers as far south as Florida saw the show, too.

— **Francis Reddy,** senior editor

An all-red aurora is a memorable sight. Wade Clark of Hamilton, Washington, imaged this rare spectacle April 6, 2000. The stars of Orion shine through the aurora's crimson band. Wade Clark

ASTRO BOOKS

Q: Could you recommend an astronomy book for beginners?

— **Gerard J. Tofel,** Largo, Florida

A: For a complete beginner who wants to get to know the heavens, my strong recommendation for 50 years and counting has been ***The Stars: A New Way to See Them*** by the late H. A. Rey. There's a reason it has stayed in print since 1952. You'll fall in love with Hans Rey's drawings, which make the constellations wonderfully easy to recognize. Rey is much better known for his *Curious George* storybooks for kids, but his astronomy writings are deservedly a big part of his legacy.

For a simple introduction to the universe's content, with brief text blocks and an emphasis on gorgeous pictures, you'll want ***Planets, Stars, and Galaxies*** (2007) by space artist David A. Aguilar. It's aptly subtitled, "A visual encyclopedia of our universe." ***A Field Guide to Stars and Planets*** (1999), Jay M. Pasachoff's contribution to the Peterson Field Guides series, is a good introductory handbook.

For information on how to get started in astronomy as a hobby — including choosing the right equipment — as well as an introduction to the science of the stars, I immodestly recommend my own book, ***Astronomy for Dummies*** (2005).

Finally, take a look at ***NightWatch: A Practical Guide to Viewing the Universe*** (1998) by Terence Dickinson and several illustrious collaborators. It may be just your cup of tea. — **Stephen P. Maran,** NASA Goddard Space Flight Center, Retired

COUNTING SUPERNOVAE

Q: How many supernovae explode each second in the universe?

— **Allen Dailey,** Sedona, Arizona

A: Astronomers estimate about seven supernovae occur every millennium in a galaxy that shines as bright as 10 billion Suns. Galaxy surveys tell us the average contribution from all galaxies, big and small, within a given volume of space. Each cubic megaparsec (a volume

GLOSSARY OF TERMS

coronal mass ejection (CME)
Billion-ton eruptions of ionized gas from the Sun's outer atmosphere, or corona.

cubic megaparsec
A volume of space about 3 million light-years on a side.

interferometer
A device that uses wave interference to measure minute angles.

observable universe
The portion of the universe astronomers can detect. It comprises 12 trillion cubic megaparsecs.

type Ia supernova
The most luminous type of exploding star; it signals the detonation of a white-dwarf star that gained mass from a companion star.

about 3 million light-years on a side) contains the equivalent light of roughly 200 million Suns.

We also need to know the volume of the observable universe. Measurements of the cosmic microwave background and supernova studies tell astronomers that the observable universe contains about 12 trillion cubic megaparsecs.

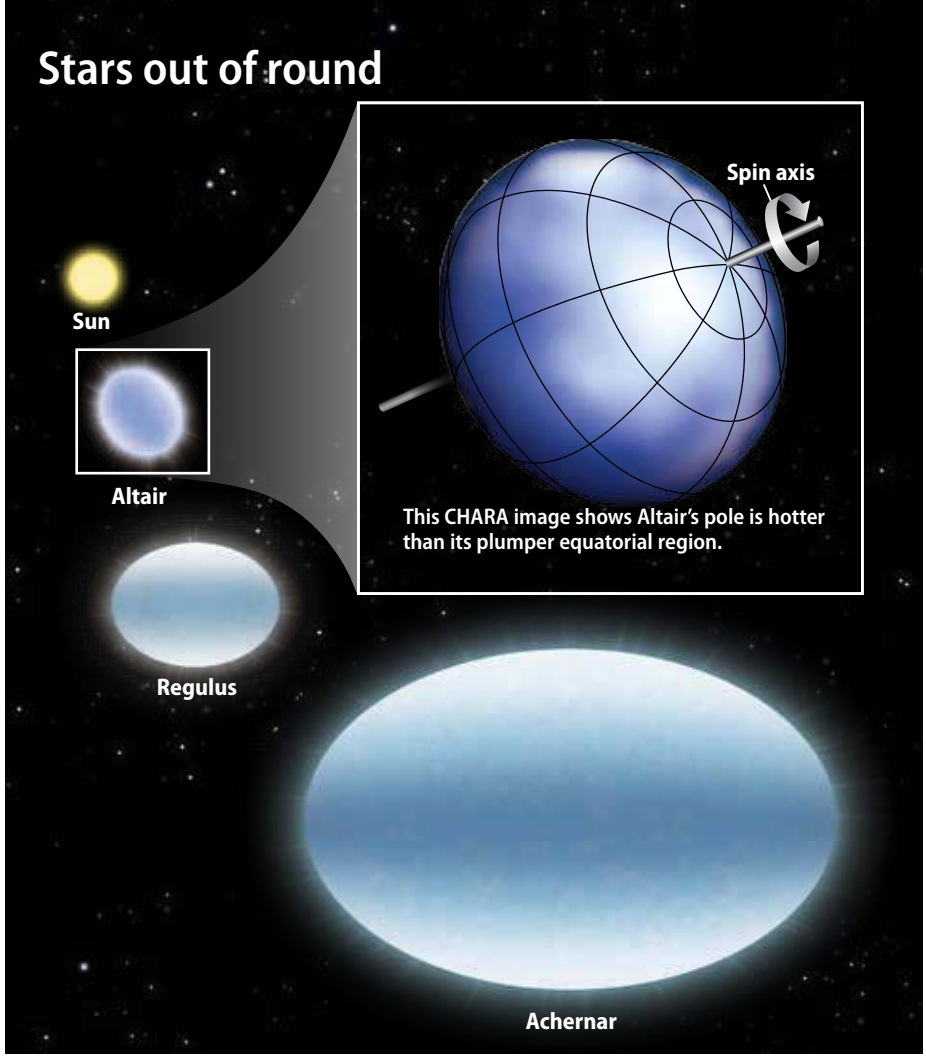
Putting these numbers together, **about 40 supernovae are exploding somewhere in the universe every second.** However, light from most of these events won't reach Earth for billions of years, if ever.

The most sensitive instruments now can detect type Ia supernovae out to about 10 billion light-years. Within this volume, we'd expect two observable supernovae to occur every second.

In 2007, the International Astronomical Union officially named a record 572 supernovae. This is 0.001 percent of the potentially observable events that year. When it comes to supernovae, we still have a keyhole view of the cosmos.

— **Robert Quimby,** California Institute of Technology, Pasadena, California

Is orbiting space junk a threat to the International Space Station? Listen at www.Astronomy.com/toc.


Stars out of round
Spin axis
Sun
Altair
This CHARA image shows Altair's pole is hotter than its plumper equatorial region.
Regulus
Achernar
Astronomy: Roen Kelly; Inset: John Monnier/Univ. of Michigan, Ann Arbor/ESO

Optical interferometers allow astronomers to image the disks of Sun-like stars. This diagram compares several fast-spinning, main-sequence stars with the Sun. Last year, a team led by John Monnier at the University of Michigan, Ann Arbor, imaged Altair. The star spins at 638,000 mph (1 million km/h) at its equator, or roughly 60 times faster than the Sun.

SEEING STARS

Q: Can telescopes see a star's disk?

— **Timothy J. Morris,** Sutton Coldfield, England

A: Yes. The distances to most stars are so great that even the largest, the supergiants, appear only as points of light through normal telescopes. But a few supergiants, such as Betelgeuse, are big enough and close enough that large ground-based telescopes using special techniques can resolve them. **In 1996, the Hubble Space Telescope directly imaged Betelgeuse's disk.**

To study smaller Sun-like stars, astronomers use an array of small telescopes called a long-baseline optical interferometer. Combining the scopes' light gives astronomers the resolution of a "super telescope" with an aperture of hundreds of meters.

The Center for High Angular Resolution Astronomy (CHARA) array on Mount Wilson, California, routinely measures the diameters of main-sequence stars. In 2007, CHARA produced a picture of the surface of Altair, the first main-sequence star other than the Sun to be imaged. Despite Altair's 0.003" angular size, CHARA revealed shape and temperature variations resulting from the star's rapid rotation.

More images, including those of interacting binaries and spotted stars, are in the works. Besides providing the first close-up views of stars and their environs, such images provide important tests of stellar models. — **Hal McCalister,** Georgia State University, Atlanta

Send your questions via e-mail to: **askastro@astronomy.com**; or write to **Ask Astro, P. O. Box 1612, Waukesha, WI, 53187.** Be sure to tell us your full name and where you live. Unfortunately, we cannot answer all questions submitted.

Your 20-year solar eclipse planner

Between now and 2028, Earth will witness 15 total solar eclipses. Here's your guide to these extraordinary events. **by Michael E. Bakich**

What is Earth's most spectacular recurring natural event? Without question, it's a total eclipse of the Sun. Experience darkness at noon just once, and you'll never forget it.

No matter how much a talk, video, news story, or this article builds your expectations, a total eclipse will not disappoint you. But it has to be total — a partial just won't do. Partial eclipses are like almost winning the lottery — there's no comparison.

Astronomers have calculated when eclipses will occur for the next millennium and beyond. I'll outline the best events in the near future. The next 20 years contain 15 total solar eclipses. Four offer totality (the time when the Moon completely hides the Sun's face) in excess of 5 minutes. Two are even rarer eclipses that exhibit both annular (which leaves a ring of the Sun's disk around the Moon) and total phases. All are worth seeing. Even if this article inspires you to travel to only one, you'll thank me for the rest of your life.

I've listed the eclipses in chronological order. Pick the ones that interest you, and start making plans. Get serious about the trip no less than 18 months before eclipse day. For detailed information — including cloudiness forecasts — visit NASA's eclipse web site, managed by veteran eclipse chaser Fred Espenak. He posts information about upcoming events several years in advance. You'll find the site at eclipse.gsfc.nasa.gov/eclipse.html.

The diamond rings mark the start and end of totality. The first diamond ring is when the best part of the eclipse begins and the second diamond ring marks the spectacle's end. Adam Clayson

July 22, 2009

I didn't plan to list the best eclipse first. It just happened that way. By "best," I mean this event has the longest duration of totality anyone now alive will see. At the point of maximum eclipse, the Moon will completely occult the Sun for 6 minutes, 39 seconds.

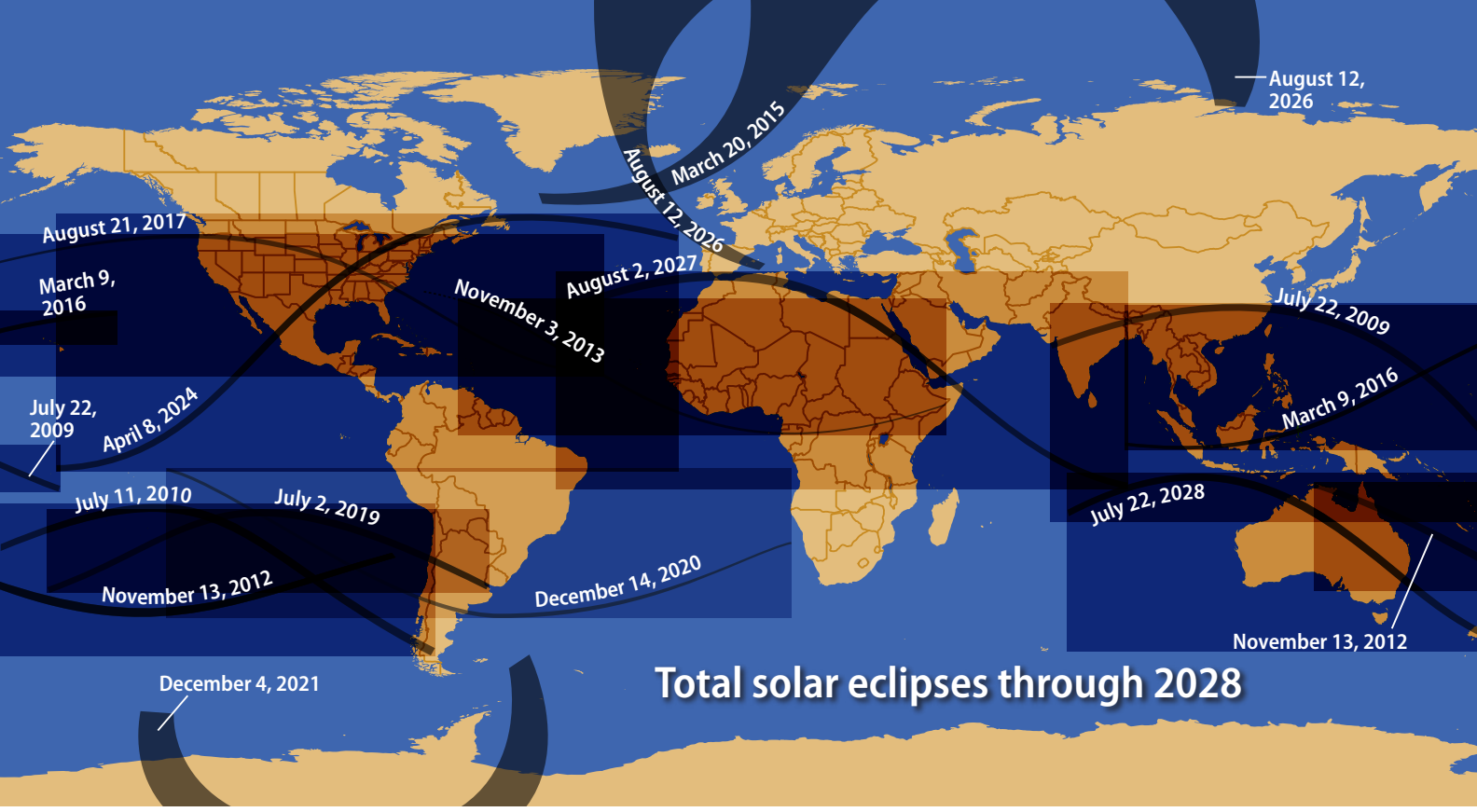
It's a safe estimate that more people will experience this eclipse than any in history because the path of totality passes over one of the world's most populous regions. The path of the Moon's umbral shadow (under which you'd experience totality) begins in India and moves through Nepal, Bangladesh, Bhutan, and China. Totality in Shanghai, China's largest city with a population near 20 million, will last 5 minutes.

Observing from land is only one option for this event. You could choose to cruise to the point of greatest eclipse, which lies in the Pacific Ocean. By doing so, you'll gain more than a half-minute of totality and maintain a great range of mobility if clouds appear.

July 11, 2010

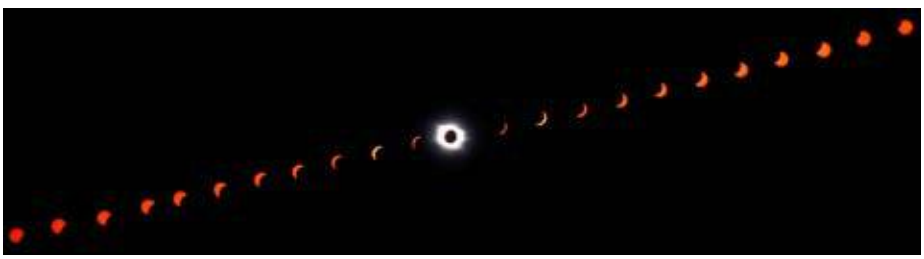
If you like exotic destinations, this eclipse plunges Easter Island — famous for its huge stone statues — into darkness for more than 4½ minutes. The point of greatest eclipse, where totality lasts 5 minutes, 20 seconds, is in the Pacific Ocean north of the island.

Almost as exotic and definitely easier to reach, Tahiti and the Society Islands lie



This chart shows the paths of totality for the next 15 total solar eclipses. See the description of each eclipse for more details. *Astronomy:* Roen Kelly after Fred Espenak, NASA/Goddard Space Flight Center

in the eclipse's path some 2,500 miles (4,000 kilometers) from Easter Island. The duration of totality throughout French Polynesia lasts approximately 3½ to 4½ minutes.



By using time-lapse photography and a wide-angle lens, or by combining individual images, you can produce a series like this one. Daniel Schechter

November 13, 2012

Twenty-eight months after the Easter Island spectacle, an eclipse with totality lasting 4 minutes, 2 seconds will begin in Australia. Greatest duration of totality occurs in the southern Pacific Ocean 1,334 miles (2,147 km) east of Auckland, New Zealand. For cruise groups wishing to stay a bit closer to land, the centerline of totality passes only 375 miles (600 km) north of New Zealand. There, totality will last more than 3½ minutes. No doubt, many travelers will take this opportunity to visit the Land Down Under. I plan to be one of them.

November 3, 2013

In early November 2013, the first of the two "hybrid" eclipses on our list occurs. A hybrid eclipse happens when the Moon lies just close enough to Earth to create an umbra along part of the path. At the beginning and end of the event, Earth's surface lies beyond the end of the Moon's umbra. In these locations, observers see an annular eclipse.

Annular eclipses don't approach the majesty of totals, so most travelers will head for the point of greatest eclipse. This location sits in the Atlantic Ocean just off the west coast of central Africa, and offers 1 minute, 40 seconds of totality. This isn't nearly as long as the three previous eclipses, but, hey, it's still totality.

March 20, 2015

A partial solar eclipse October 23, 2014, that observers across the United States will see may whet the appetites of eclipse-goers for the 2015 total event. This far-northern eclipse tracks across the North Atlantic during a time when clouds and inclement weather prevail. If you find a clear spot near the point of greatest eclipse, you can experience up to 2 minutes, 47 seconds of totality. Because of this eclipse's northern location, you can combine it with a land-based tour to experience the aurora borealis. The point of greatest eclipse lies 450 miles (725 km) from Reykjavik, Iceland, and 640 miles (1,030 km) from Oslo, Norway, both great locations for seeing the northern lights.

March 9, 2016

Remote locations abound on this list, and the 2016 total eclipse, which boasts 4 minutes, 9 seconds of totality, is another example. Although this eclipse passes over Sumatra, Borneo, and Sulawesi, the point of greatest eclipse (and probably the best weather) occurs in the Pacific Ocean some 1,350 miles (2,175 km) north of

Following eclipses leads observers to some remote and exotic destinations. This group observed the March 29, 2006, total solar eclipse from the Sahara Desert. Jacques Guertin

Papua, New Guinea. Almost all of Australia will see some percentage of a partial eclipse, but none of that continent will experience totality.

August 21, 2017

Fellow citizens of the United States, take note. The first of two total solar eclipses to cross our country in 7 years occurs in the summer of 2017. Great weather should abound along most of the path of totality. It touches land in Oregon, then crosses Idaho, Wyoming, Nebraska, Kansas, Missouri, Kentucky, Tennessee, Georgia, and South Carolina before heading into the Atlantic Ocean.

Casper, Wyoming, and St. Joseph, Missouri, lie directly on the centerline. Near misses include Salem, Oregon; Kansas City and Columbia, Missouri; Nashville; and Charleston, South Carolina. Many large cities, including Portland, Denver, St. Louis, and Atlanta, sit within easy driving distance of totality. The point of greatest eclipse — which offers 2 minutes, 40 seconds of totality — lies only 83 miles (135 km) northwest of Nashville and less than 7 miles (11.3 km) from Interstate 24.

Michael E. Bakich *is a senior editor of* Astronomy *who hopes to view the majority of the eclipses on this list.*

July 2, 2019

If you plan to see 2019's total solar eclipse, plan on water, water, and more water. If that's OK with you, you'll experience 4 minutes, 33 seconds of totality at the point of greatest eclipse. This location lies nearly 1,700 miles (2,740 km) southwest of the Galapagos Islands. For those that want to experience this eclipse at its longest, I think this will be one of the least accessible and most expensive of all the events on this list.

December 14, 2020

Residents in central Chile and Argentina find themselves well-placed for an eclipse with maximum totality lasting 2 minutes, 10 seconds. Although much of the eclipse path runs along oceans, the point of greatest eclipse falls over land. This event occurs within a week of Southern Hemisphere summer, so travel conditions should be good. Make sure you get out at night to see the southern constellations and two of the Milky Way's satellite galaxies, the Magellanic Clouds.

December 4, 2021

Remote barely describes where you'll need to be to see this eclipse. It's total only over Antarctica, and then for a paltry 1 minute, 54 seconds. You want an exclusive event? Sign up with a tour heading to view this eclipse, and you'll be among about a hundred people to experience its totality, out of Earth's 6 billion inhabitants.

April 20, 2023

Our string of four distant destinations ends with the second of the two hybrid eclipses on our list. It occurs 16½ months after the Antarctic event, so more people may be eager to travel to Indonesia, despite the weather prospects. The point of greatest eclipse provides only 1 minute, 16 seconds of darkness, so many travelers might want to combine a short vacation in Australia with this event.

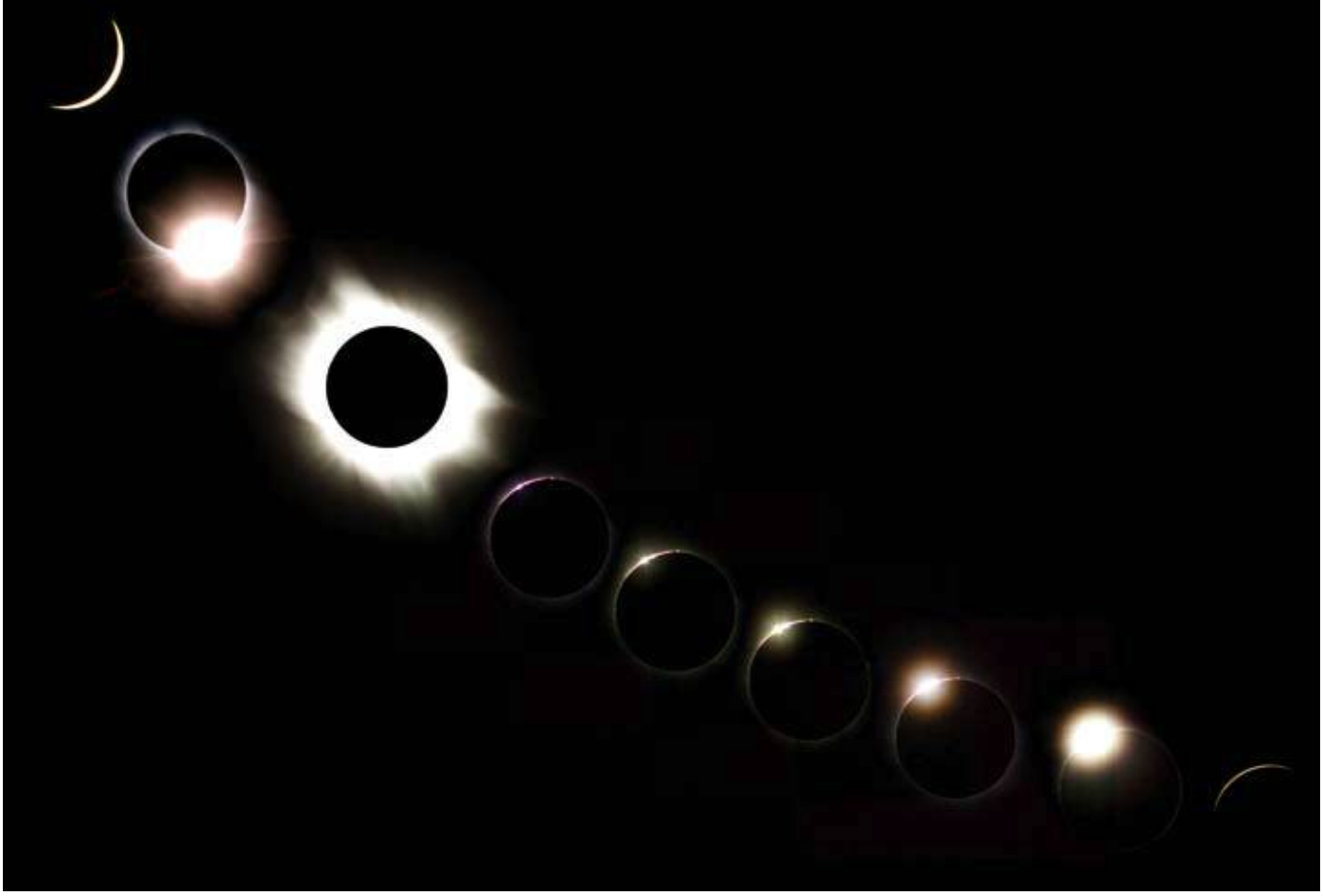
April 8, 2024

The second United States eclipse on our list has its point of greatest duration near the small town of Nazas, Mexico, just southwest of Torreón. Totality there lasts 4 minutes, 28 seconds. Not many of us may travel to Nazas, however, because a nice swath of the central and eastern United States will experience more than 4 minutes of totality.

Texas will be the first state to darken under the Moon's shadow. There, the eclipse will be darkest and weather prospects will be the best. So, put on your 10-gallon hat and head to San Antonio, Austin, or Dallas, each of which lies within easy reach of the centerline. Indianapolis, Cleveland, and Rochester, New York, also lie quite close to the central

First contact marks the eclipse's beginning. It occurs when the Moon, traveling eastward, catches up to the Sun and takes the first tiny bite out of its disk. David Harrington

Second contact marks the moment when the Moon's disk first hides the Sun. By taking close-up shots, this photographer captured prominences arching above the Sun. Terry Cuttle



Most eclipse photographers image the diamond rings and the interval of totality between them. Astronomers call the "droplets" of sunlight visible at this time Bailey's Beads. Ian Wardlaw

path, but weather at those locations in April may not be as nice as that in Texas.

And here's a special treat for those living in or near Cape Girardeau, Missouri, and Carbondale, Illinois: If the sky is clear on August 21, 2017, and April 8, 2024, you'll experience totality twice without traveling anywhere.

August 12, 2026

At first glance, an eclipse with a maximum totality lasting only 2 minutes, 20 seconds over northern Greenland and the western tip of Iceland might seem problematic. Luckily, this one occurs in mid-August when the weather is still fair. If Iceland's lure to you is strong, here's a chance to experience Reykjavik and its surroundings along with totality.

August 2, 2027

The second-to-last eclipse on our list offers the longest totality anyone now alive will ever see — 6 minutes, 23 seconds. If this description sounds familiar, it's how I described the first eclipse on this list. Since then, however, 18 years have passed, and this is the new "longest-ever" eclipse. Not until February 16, 2045, will Earth again experience totality in excess of 6 minutes. Only one other 21st-century eclipse — that of May 22, 2096 — features more than 6 minutes of totality. I'm guessing I'll miss that one.

Intrepid travelers should have no concerns about the weather for the 2027 eclipse. Its track begins in the eastern Atlantic Ocean, then heads through Morocco and Spain. The weather should get a lot better for the best part of the eclipse, which passes through Algeria, Libya, Egypt, and Saudi Arabia.

July 22, 2028

Our list ends with another great eclipse. This one will feature 5 minutes, 10 seconds of totality and an easily reachable land path. This event tracks about three-quarters of Australia's length. For maximum duration of darkness, head to the northern part of Western Australia near Drysdale River National Park. The least amount of totality an observer from the centerline in that country will see is 3¾ minutes. This "worst case" location lies between two of Australia's largest cities, Sydney and Brisbane.

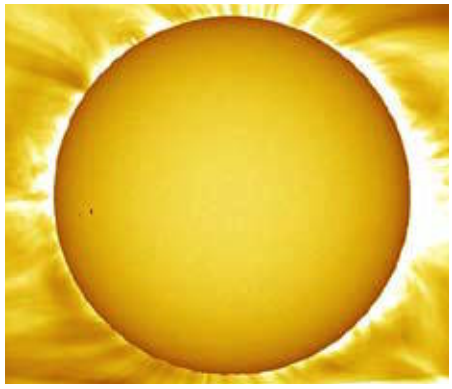


Image-processing techniques allow for some unusual photographs. This composite shows the eclipsed Sun's corona, but the imager also has overlaid the Sun's full disk as it appeared just prior to the start of the eclipse. Anthony Ayiomamitis

Adventure awaits you

With this list in hand, you can plan to see one or more of these upcoming total solar eclipses. Each offers spectacular beauty and one of the rarest of natural wonders — darkness at midday. Fare thee well, fellow travelers.

Sky testing Orion's 102mm f/7 ED

Crave an apochromatic refractor but your budget won't allow it? Here's a good scope to consider. **by Tom Trusock**

The apochromatic refractor is one of my favorite instruments for observing the universe. These scopes provide excellent light transmission, lack the drawbacks of a central obstruction, and yield terrific views. Another plus: The 4-inch class is easily portable. The usual downside of these wonderful scopes is sticker shock. They can be pricey.

Orion's new 4-inch (102 millimeters) f/7 ED telescope fills the gap between price and performance. At $995.95, it's a great scope for visual observers and imagers who would like an affordable apochromatic refractor. The scope's air-spaced doublet objective boasts one extra-low dispersion (ED) element for improved color correction.

Tom Trusock *is a prolific telescope reviewer who observes under the dark skies of Ubly, Michigan.*

Hands on

At around 23 inches (58 centimeters) long and 8.1 pounds (3.7 kilograms), the Orion 102mm f/7 ED is only a little bigger than some 80mm telescopes and is an attractive option for those seeking a travel scope. It sports a retractable dew shield and comes equipped with a press-fit lens cover. The scope kit includes tube rings and a Vixen-compatible dovetail, but add an extra $89.95 if you want a case.

Right out of the box, the Orion 102mm f/7 ED presents itself well. The finish is an attractive pearly paint.

The dual-speed rotatable focuser is a 2" Crayford design with an 11:1 fine-focus reduction gear. It has a dovetail base compatible with Orion finders (option).

The focuser's oversized knobs make it eye-catching and appealing. The tension is adjustable, although the default setting worked well for every eyepiece I tried. Motions were smooth, with just a slight ratchet at some points. Typically, this was barely noticeable, but, on occasion, it made precise focusing a little difficult.

Initially, I found the scope's performance disappointing. Bright in-focus stellar images looked cross-shaped and maintained this form while rolling through focus. The defocused images showed four dark indentations. Such images are a typical result of pinched optics. In this case, the factory overtightened the scope's collimation (alignment) screws.

After I contacted Orion, the company sent me detailed instructions on how to solve the problem by successive loosening of these screws. This corrected the pinch but threw the telescope slightly out of collimation.

Fortunately, it's easy to align doublets, and, after 20 minutes, I had licked the problem. Relieving the pinch greatly improved high-power performance.

Deep views

But it's the focused views that tell the tale, and those were quite pleasing. The 102 ED is a rich-field telescope, and it shows wide swaths of sky. This makes it superb for viewing open clusters and large regions of nebulosity. The Pleiades (M45) was a stunning target, and the scope

A bigger lens grabs more light. The scope's 102mm aperture gathers 3.4 times more light than a 60mm. This air-spaced doublet objective includes an extra-low dispersion element to provide better color correction.

Specifications

Orion's 102mm f/7 ED

Type: Apochromatic refractor
Aperture: 4 inches (102 millimeters)
Focal length: 28.1 inches (714mm)
Focal ratio: f/7
Tube length: 23 inches (58 centimeters)
Assembled weight: 8.1 pounds (3.7 kilograms)
Dimensions: 4" by 3.75" by 1.25" (102 mm by 95 mm by 32 mm)
Included: Two 114mm inside-diameter tube rings; 8" dovetail mounting plate; 1¼" eyepiece adapter; dovetail base for finder scope; dual-speed (11:1), rotatable 2" focuser; extendable lens shade
Price: $995.95

The 102mm f/7 ED's compact 23-inch (58 centimeters) tube, 8.1-pound (3.7 kilograms) weight, and rich-field views make it an ideal scope to take along on trips. Telescope images: *Astronomy*: William Zuback; Background M42: NASA/ESA/STScI/Hubble Space Telescope Orion Treasury Project Team

showed hints of the Merope Nebula (NGC 1435). The Double Cluster (NGC 869 and NGC 884) also was terrific.

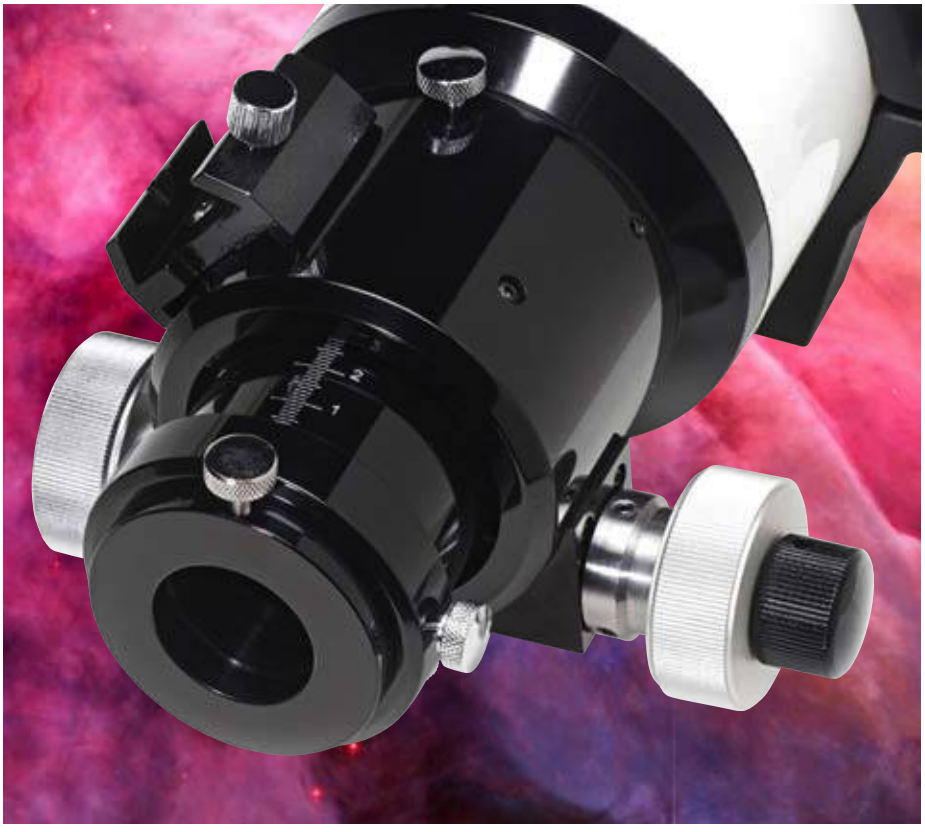
I spent a fair amount of time in one of my favorite winter constellations — Orion. The Orion Nebula (M42) is a joy through any aperture. I was unable to pick out Barnard's Loop (Sh 2–276), but that was likely due to poor sky conditions.

Turning to Saturn, the scope handled magnifications of 200x without significant image breakdown. As the rings thin, the Cassini Division is ever harder for a small scope to pick out, but the Saturn system still captures your full attention. Mars was a distinctive pale-red dot that showed some surface features.

Pointing the 102 ED at the Moon revealed a small amount of secondary color in the shadows of lunar mountains. The hue was either purple or yellow-green, depending on which side of focus I was favoring at the moment.

This didn't detract from my enjoyment of the views, and hunting tiny craters within Clavius was fruitful. I nabbed more than 25 craterlets. While this isn't the most I've managed to see, it's a respectable number for a 4-inch telescope.

Overall, the Orion 102mm f/7 ED performed well. Its light weight and low cost make it appealing to travelers. The telescope offers a good balance of features and performance for the money. It's well worth your consideration if you're looking for a good scope at a price that won't break the bank.



The scope comes with a 2" rotatable Crayford focuser that sports dual speeds.

Contact information

Orion Telescopes and Binoculars
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[w] www.telescope.com

Inside Arizona's meteorite treasure chest

Hidden away at Arizona State University, tens of thousands of space rocks tell researchers the solar system's story.

by Raymond Shubinski

Meteorites tell scientists the fascinating story of our solar system. And at Arizona State University (ASU), you'll find a great facility for deciphering that story — the Center for Meteorite Studies (CMS). The facility sits on ASU's main campus in Tempe, nestled among the buildings of the Bateman Physical Science Center.

The collection

The El Dorado of the facility is the vault room, according to Director Meenakshi Wadhwa. This space is where the CMS stores and maintains its meteorites. Famed American meteoriticist Harvey Nininger's original collection resides here, but the CMS has drawers and cabinets holding treasures of which Nininger could only have dreamed.

The collection includes six shergottites, among the rarest of all meteorites. Scientists believe shergottites originated on Mars because their composition can only have been produced by their formation on a large differentiated body like a planet. Shergottites get their name from the Indian village of Shergotty, where one of them fell August 25, 1865.

The CMS has more than 690 pounds (313 kilograms) of one meteorite, the chondrite from Hugoton, Kansas, that Nininger identified in 1927. Pieces held by the center account for more than 90 percent of the total material recovered. By contrast, the collection contains more than 45 meteorites with weights less than 1 gram. Two — the Kharkov, Ukraine, meteorite and the Siminod, France, meteorite — weigh only 0.02g each.

Wadhwa's favorite is a small specimen known as the Los Angeles meteorite. Collector Bob Verish found this innocuous rock — a shergottite — in the Mojave Desert while prospecting for meteorites

CMS' current leader is just right for the job

In October 2006, Meenakshi Wadhwa became Arizona State University's director of the Center for Meteorite Studies. She had served as curator of the meteorite collection at the Field Museum of Natural History in Chicago for 11 years.

She attended Panjab University in India, where she studied geology as an undergraduate. Recent finds of martian meteorites fascinated her, and she began to focus on planetary geology. In 1994, she received her Ph.D. from Washington University in St. Louis.

Wadhwa's specialties lie in deciphering the origin and evolution of planetary bodies through geochemical and isotopic means. She utilizes high-precision spectrometric techniques to investigate a wide range of solar system materials, including meteorites of martian origin, Moon rocks, and samples returned by spacecraft missions such as Genesis and Stardust. In studying these diverse materials, her goals are to decipher the processes involved in their formation and to determine when they formed.

Applying a multidisciplinary approach to the study of solar system evolution is her goal. "Let's bring in geochemistry and an arsenal of other sciences and engineering techniques to tell the story," she says. This will allow development of a detailed timeline for the formation of the objects now contained in collections such as those at the CMS.

Wadhwa has an asteroid named for her (8356 Wadhwa), and the Meteoritical Society has awarded her the Nier Prize for significant contributions in the field of meteoritics and planetary studies. With a background and resumé as rich as this, it's no wonder she has created a lot of excitement and activity at the CMS. — *R. S.*

Meenakshi Wadhwa has directed the Center for Meteorite Studies at Arizona State University since October 2006.

The vault of the Center for Meteorite Studies contains more than 1,555 discrete meteorite falls and finds, the largest university-based collection in the world. All images: *Astronomy:* Michael E. Bakich

The Los Angeles meteorite came from Mars. While hunting for meteorites in the Mojave Desert October 30, 1999, meteorite collector Bob Verish found two rocks since classified by UCLA as martian basaltic shergottites.

This piece of the Millbillillie eucrite meteorite shows the classic black fusion crust created during its passage through Earth's atmosphere. This stone fell in October 1960, but searchers didn't find the first specimen until 1970.

The Norton County meteorite fell in Kansas at about 4 P.M. February 18, 1948. This meteorite is a type of achondrite called an aubrite. Typically, aubrites are light-colored with brownish fusion crusts. They are iron-poor, but rich in magnesium.

in 1999. The melted outer layer (the fusion crust) shines like black glass. Martian meteorites are Wadhwa's passion, and she hopes to unravel the complex geological history of Mars from comparative studies of the chemical and isotope compositions of known examples.

Other research

Down the hall from the vault are the labs where the real work is done. These rooms hold mass spectrometers and computers with huge databases. The CMS' overall aim is to push the boundaries of our knowledge about the solar system's earliest days (see "Scientists find Earth's age through meteorites," page 82).

Collections Manager Laurence Garvie is one of the center's researchers. He deciphers early solar system processes by using high-resolution microscopic and spectroscopic meteorite analysis. Garvie focuses on carbonaceous chondrites, which chronicle the physics and chemistry that shaped our solar system.

Garvie's current projects include studying the structure, distribution, and formation conditions of organic materials in carbonaceous chondrites. Understanding the relationship between organic and inorganic components in primitive meteorites may reveal important information on abiotic organic processing during solar system formation.

Carbonaceous chondrites are among the most primitive known meteorites and contain some of the earliest solid grains to have formed directly from the solar nebula (the cloud of gas and dust from which the Sun and the planets formed).

These solid grains contain elements such as calcium and aluminum. Researchers think they predate Earth's formation. The Center's holdings include 35 distinct carbonaceous chondrites.

Other members of the Center's staff and faculty, which number 14, are working on a variety of projects, including investigations of laboratory and terrestrial analogs of Martian surface rocks analyzed by NASA's Mars Exploration

The Allende carbonaceous chondrite meteorite fell at 1:05 A.M. February 8, 1969, creating a brilliant fireball. Pieces rained down over Pueblito de Allende in the state of Chihuahua, Mexico. Scientists have dated inclusions in this meteorite older than Earth. The CMS has many specimens of this important meteorite.

CMS has a rich history

The CMS had its beginnings in the late 1950s. In 1960, ASU purchased half of Harvey H. Nininger's world-famous meteorite collection. The British Museum had bought the other half, and some were concerned that these spectacular meteorites might disappear into private hands, becoming unavailable to researchers and scholars. In 2010, the CMS will celebrate its 50th anniversary — that's half a century of preserving this special assemblage of meteorites.

In 1965, Nininger and his wife endowed the Nininger Meteorite Award, which the CMS presents annually. This prize recognizes outstanding student achievement in meteoritics.

With the Nininger collection at the core, the center has amassed more than 1,555 distinct meteorite falls and finds. This number makes ASU's the largest university-held collection in the world.

The founding director of the CMS was ASU Professor Emeritus Carleton Moore. Moore oversaw the center's early years and was active in research. In the 1970s, he was a principal investigator for NASA's Apollo lunar sample return program. His major research involved chemical studies of these samples.

Many of the techniques used in the 1970s, such as mass spectrometry (identifying a sample's chemical composition), are still utilized at the center. Despite his Emeritus status, Moore continues to make valuable contributions to the research and educational mission of the center. — *R. S.*

Raymond Shubinski *is a contributing editor of* Astronomy *and a long-time meteorite collector.*

Scientists find Earth's age through meteorites

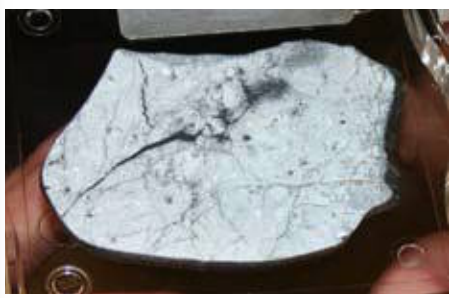
The generally agreed upon age for Earth is 4.6 billion years, and meteorites gave us this important date. In the mid-17th century, James Ussher (1581–1656), the Bishop of Dublin, used biblical genealogies to determine a date for Earth's creation. His work led to an Earth about 6,000 years old. It quickly became apparent that this was much too young an age to explain ongoing geological discoveries.

In the 18th century, French naturalist Georges-Louis Leclerc de Buffon (1707–1788) used slowly cooling iron spheres in an attempt to date Earth, to no avail. Finally, in 1953, American geochemist Clair Cameron Patterson (1922–1995) found a solution.

Scientists knew that isotopes of uranium slowly decay into isotopes of lead. In his pioneering work, Patterson measured the isotope composition of lead in a piece of Arizona's Canyon Diablo meteorite, which resulted in the first accurate measurement of Earth's age.

The CMS laboratories are refining the solar system's age with incredible precision. By continuing to study trace isotopes contained in the most primitive meteorites, CMS scientists are talking about ages with accuracies within hundreds of thousands of years. — *R. S.*

The center's research facilities are top-notch. They include several laboratories for meteorite classification and chemical analysis using mass spectrometry.



This meteorite originated on the Moon. Scientists dubbed it NWA 482 because collectors recovered it in northwest Africa. Collectors found the original stone in late 2000.

Rovers and of solar wind samples returned by NASA's Genesis mission.

The future

The museum contains exhibits on meteorite types and how scientists study them. It is free and open to the public and used by local schools.

The center provides materials and activities about meteorites to teachers. Its proactive outreach program includes additional exhibits, an astronomy open house, and other events. "All of this supports our mission of sharing this knowledge with students, educators, and the general public," Wadhwa says.

Wadhwa adds that the study of meteorites "needs the support of interested amateurs and meteorite collectors who are willing to get out into the field and find new specimens." ASU's collection has grown by purchases and trades with collectors and other institutions.

In July 2006, ASU opened the School of Earth and Space Exploration as part of the College of Liberal Arts and Sciences. Wadhwa's challenge is to bring the powers of science and engineering together so the center's staff can push the boundaries of solar system discovery. With such a fabulous collection of meteorites to study, expect cutting-edge results sooner rather than later.

See more examples of meteorites at www.Astronomy.com/toc.

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Observing Basics

by Glenn Chaple

See the red star round-up

Herschel's Garnet Star and Hind's Crimson Star burn red and brightly this month.

Have you ever been "Purkinjed?" If you're a variable star observer, you're susceptible to this phenomenon, called the Purkinje effect, whenever you try to make a visual magnitude estimate of a red star.

Stare at the star directly, and its crimson light excites your retina. As a result, you perceive the star as being brighter than it really is. To avoid being Purkinjed by this color of star, I either quick-glance between it and the nearby field stars I'm comparing it to, or I defocus my telescope to reduce its intensity.

Red stars aren't the exclusive domain of variable star observers. Celebrated examples like Herschel's Garnet Star (Mu [μ] Cephei) and Hind's Crimson Star (R Leporis) are true showpieces that anyone can enjoy.

Invite passersby at a public star party to view one of these stellar rubies through your telescope. You are guaranteed to jack up the "Wow!" factor. Sometimes it's fun to get Purkinjed!

Through a telescope, Herschel's Garnet Star appears redder than in this image. Cameras accumulate and store light better than the human eye, so they increase the brightness of celestial objects. Anthony Ayiomamitis

Two of my favorite red stars occupy the constellation Cepheus the King, currently well-placed for early evening observing. The first is Mu, located midway and slightly southwest of a line joining Alderamin (Alpha [α] Cephei) and Delta (δ) Cephei. (See the finder chart on page 85.)

Mu is a semiregular variable star, drifting lazily between magnitudes 3.4 and 5.1. Although visible to the unaided eye, the "Garnet Star" best reveals its ruddy hue when scrutinized through binoculars or a small telescope.

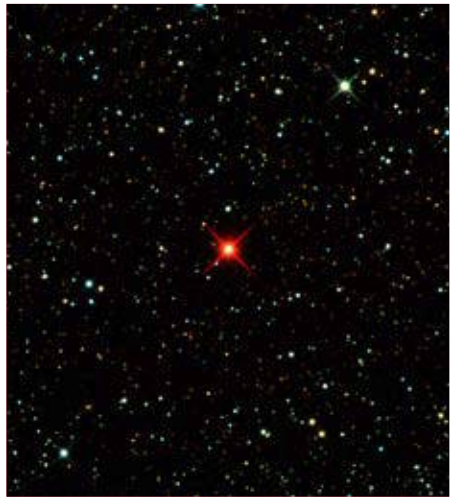
Like the first-magnitude star Betelgeuse, Mu is a cool red supergiant. And, like Betelgeuse, it isn't candy-apple red.

What color you perceive depends on a number of factors, including your visual sensitivity to red light, whether the star is near maximum or minimum brightness, atmospheric conditions, and the aperture and optical quality of your telescope or binoculars. For those reasons, Mu can appear to be anywhere between yellow-orange and red-orange. Still, Mu's color is quite impressive when you compare it to the nearby Alpha — a pure white star.

Want to really see red? Try a carbon star! A shell of carbon and carbon compounds envelop such stars. The carbon absorbs blue light, making these stars true celestial blood drops. S Cephei is a carbon star. You'll need a telescope to see it, as S Cep gravitates between magnitudes 7.5 and 11 in a 490-day cycle.

To find S Cephei, use low power to sweep the area roughly midway between Gamma (γ) and Kappa (κ) Cephei. A small asterism comprising four 6th- and 7th-magnitude stars will help narrow the area you need to search.

I try to make a brightness estimate of S Cep once every 7 to 10 days, following the anti-Purkinje tactic of defocusing the field. Once my estimate is made, I refocus and stare. S Cephei quickly evolves into a dazzling ruby-red gem!



A CCD camera attached to a small telescope captures the red variable star V Cygni at its minimum brightness. Anthony Ayiomamitis

October means Halloween in the United States. Kristin Torrey of San Bernardino, California, uses the occasion to promote backyard astronomy. She writes: "Every Halloween that the Moon is visible, I like to take a telescope out to the end of the driveway with a bag of treats (I pass out Starburst candies and Moon Pies). As the kids come by for trick-or-treat, they only get candy after they look through the telescope and tell me what they see. I am the one who has the amazing experience, right along with the lil' Spidermen, monsters, and princesses."

Great idea, Kris! Be forewarned that this Halloween you may be visited by a larger than usual trick-or-treater. By the way, I love Moon Pies.

Questions, comments, or suggestions? E-mail me at gchaple@hotmail.com.

The learn more about red stars you can observe, go to: www.Astronomy.com/toc.

Binocular Universe

by Phil Harrington

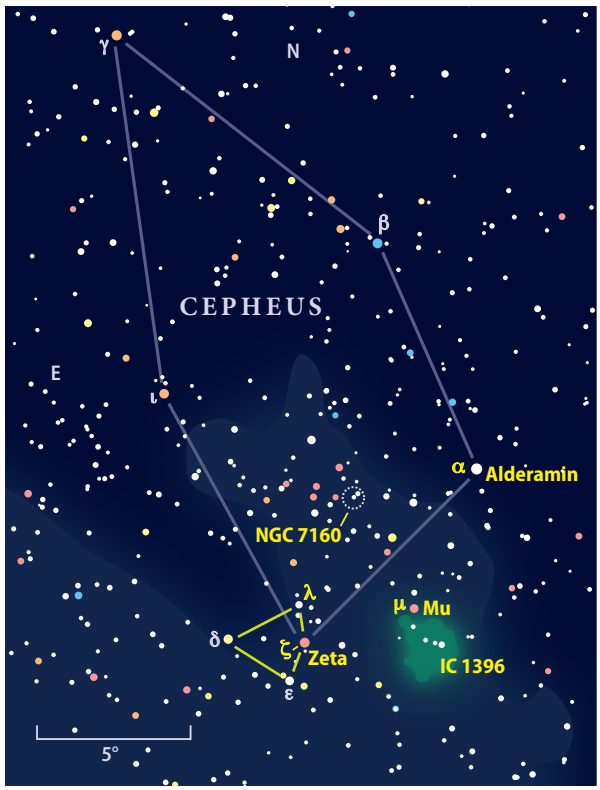
Cepheus' fall delights

Cassiopeia's husband harbors bright star clusters and a famous red variable star.

Autumn's royal family, dominated by the famous "W" of Cassiopeia the Queen, climbs high in the northeastern sky this month. But as easy as Cassiopeia is to see, spotting the house-shaped constellation of her husband, Cepheus the King, can be a challenge given today's light pollution. The effort is well worth it because the King brings with him several royal subjects to enjoy through binoculars.

Let's begin with a real eye-catcher, the red star **Mu** (μ) Cephei. Mu is south of the midway point between **Alderamin** (Alpha [α] Cephei) and **Zeta** (ζ) Cephei, which form the "floor" of the house.

After viewing Mu in 1783, William Herschel described it as "a very fine deep garnet colour . . . and a most beautiful object, especially if we look for some time at a white star before we turn our telescope to it, such as Alpha Cephei, which is near at hand." This captivating description later resulted in Mu's popular nickname, "Herschel's Garnet Star."



Cepheus' royal house holds many binocular targets, including the beautiful red variable star Mu Cephei. Bright star clusters also lie within King Cepheus' realm. *Astronomy*: Roen Kelly

Mu Cephei is one of the largest and most luminous red supergiants in our galaxy. Were Mu placed in the center of our solar system, the star's edge would extend nearly to Saturn's orbit. To enjoy its vivid red color fully, follow Herschel's advice by viewing Alderamin first before turning to Mu. Their color contrast should then be immediately obvious.

Mu lies at the north end of an arc of four stars. The two stars at the south end of the arc belong to an open cluster, **IC 1396**. If the sky is dark and you hold your binoculars very steady, you should also be able to see several dim cluster stars swarming in IC 1396. Most are magnitude 9 or fainter and may be difficult to pick out through low-power binoculars. Altogether, the cluster contains 50 stars scattered across an area equal to three Full Moons laid side by side.

Photographs show that IC 1396 sits within a huge emission nebula resembling the Rosette Nebula (NGC 2237-9). Unfortunately, the nebula's deep red color makes spotting it extremely difficult. North Carolinian Tom Lorenzin reported success, however, after he taped two narrowband nebula filters to the eyepieces of his binoculars. Try it if you can and let me know your results!

After visiting IC 1396, head east to Zeta at Cepheus' southeast corner. Zeta is the brightest star in a kite-shaped asterism that includes Lambda (λ), Epsilon (ε), and Delta (δ) Cephei. When British astronomer John Goodricke discovered in 1784 that Delta was a variable star, he could not have imagined the impact his discovery would have on the size of our universe. Delta is a Cepheid variable, a special type of star that astronomers use to estimate vast distances within the Milky Way as well as to other galaxies. Delta varies from magnitude 3.5 to 4.4 over a cycle lasting 5 days, 8 hours, and 47 minutes.

Now let your attention wander north to **NGC 7160**, a bright small cluster about halfway between Alderamin and Delta, and a bit higher in the sky. NGC 7160's brightest star, a blue giant, shines at magnitude 7. Two others — one magnitude 8, the other nearly 9 — form a tiny isosceles triangle with the blue giant through 10x binoculars. The rest of the five-dozen cluster stars blur into a nebulous glow.

NGC 7160 belongs to a large stream of young stars known as the Cepheus OB2 Association. You can see the association naked-eye on dark autumn nights as a conspicuous band of starlight branching off from the main stream of the Milky Way in northeastern Cygnus and flowing into southern Cepheus.

See something interesting through your binoculars? I'd love to hear about it. E-mail me through the magazine's web site. Until next month, when we pay a call on Cassiopeia, remember that two eyes are better than one.

For additional targets in Cepheus, go to: www.Astronomy.com/toc.

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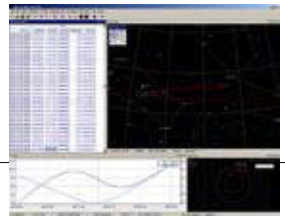

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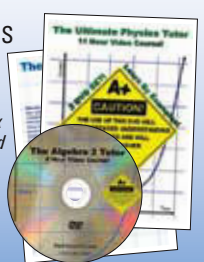

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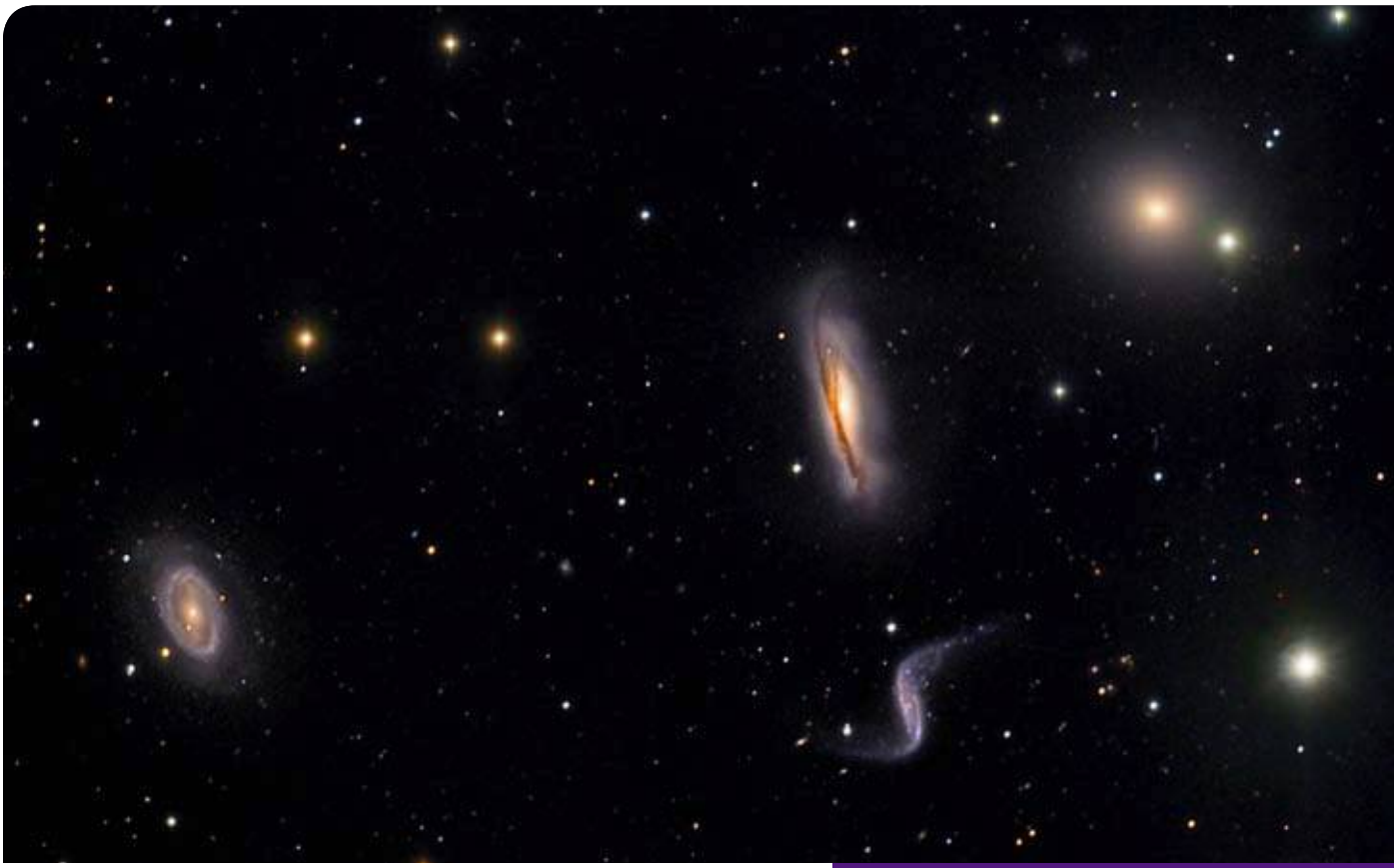

Compact galaxy group Hickson 44 (12-inch Meade LX200R Schmidt-Cassegrain telescope at f/7, SBIG ST-10XME CCD camera, LRGB image with exposures of 125, 40, 35, and 50 minutes, respectively) • Ruben Kier, Orange, Connecticut

Compact galaxy group Hickson 92 is more popularly known to astronomers and observers as Stephan's Quintet (NGC 7317, 7318A, 7318B, 7319, 7320). It was the first compact galaxy group discovered. French astronomer Édouard Stephan found it in 1877 from Marseilles Observatory. • Ruben Kier, Orange, Connecticut

The endless sea of space

In 1982, Canadian astronomer Paul Hickson published a list of 100 compact galaxy groups. Each group contained four to eight galaxies. Pictured above is Hickson 44 in Leo. The central galaxy is the tightly wound spiral NGC 3190. It tilts only 8° from edge-on. Gravitational interaction with nearby galaxies warps its central dust lane. Below center is spiral galaxy NGC 3187, with gravitational forces stretching the edges of its spiral arms into tidal tails. On the left is the barred spiral galaxy NGC 3185, and NGC 3193 sits at upper right.

^ Scorpius the Scorpion formed the backdrop for the Moon, Venus (brighter of the pair at lower left), and Jupiter in this dramatic early-morning shot. The two planets lay just more than 1° apart. (Canon EOS 5D DLSR camera, 35mm lens at f/2.8, ISO 400, composite of 15-, 8-, 3.2-, 1.3-, and 0.5-second exposures taken February 2, 2008, starting at 5:50 A.M. local time) • Tunç Tezel, Bursa, Turkey

^ Two days after the grouping to the left occurred, the waning crescent Moon, Venus (lower left of the pair of starlike objects), and Jupiter gathered into a tight triangle low in the eastern morning sky. (Canon EOS 5D DLSR camera, 50mm lens at f/2.8, ISO 200, 6-second exposure taken February 4, 2008, at 6:05:51 A.M. local time) • Tunç Tezel, Bursa, Turkey

^ The Prawn Nebula (IC 4628) is an emission nebula in Scorpius that sits about 15° south-southeast of Antares (Alpha [α] Scorpii). IC 4628 lies about 6,000 light-years away. Australian astronomer Colin Stanley Gum cataloged this object as Gum 56. (10-inch ASA astrograph at f/3.8, FLI Microline 8300 CCD camera, RGB image with 40-minute exposures through each filter) • Gerald Rhemann, Vienna, Austria

^ Emission nebula NGC 6188 is part of a dark molecular cloud in the constellation Ara the Altar. In NGC 6188, thick dust coexists with brilliantly colored hydrogen clouds. (12.5-inch RC Optical Systems Ritchey-Chrétien telescope at f/9, Apogee U16M CCD camera, SII/OIII/Hα/RGB image with exposures of 220, 220, 180, 10, 10, and 10 minutes, respectively) • Don Goldman, Orangevale, California

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The Southern Whirlpool Galaxy (M83) in Hydra is the finest barred spiral galaxy visible to northern observers. (RC Optical Systems Ritchey-Chrétien telescope at f/8, SBIG STL-11000 CCD camera, LRGB image with exposures of 615, 90, 54, and 108 minutes, respectively) • R. Jay GaBany, San Jose, California

Spiral Galaxy NGC 1532 in Eridanus interacts with NGC 1531, a smaller companion galaxy. This pair lies 70 million light-years away. (12.5-inch Optical Guidance Systems Ritchey-Chrétien telescope, SBIG ST-10XE CCD camera, LRGB image with exposures of 406, 60, 60, and 60 minutes, respectively) • Ted Wolfe, Naples, Florida

Sharpless objects 2–16, 2–17, 2–18, 2–19, and 2–20 are emission nebulae in Sagittarius that lie in the direction of the Milky Way's core. (7.2-inch Takahashi Epsilon 180ED hyperbolic astrograph at f/2.8, SBIG ST-10XME CCD camera, HαRGB image with exposures of 300, 24, 24, and 24 minutes, respectively) • Dean Salman, Tucson, Arizona

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^ Mercury (upper left) and the 2-percent-illuminated crescent Moon made an attractive celestial pair about an hour after sunset in early May. At the time, the innermost planet shone at magnitude –0.3 and measured only 7" across. (Canon EOS 300D digital SLR, ISO 400, 100-400mm lens set at 200mm and f/5.6, 4-second exposure, May 6, 2008, at 8:51 P.M. local time, taken from rural Bolu, Turkey) • Tunç Tezel, Bursa, Turkey

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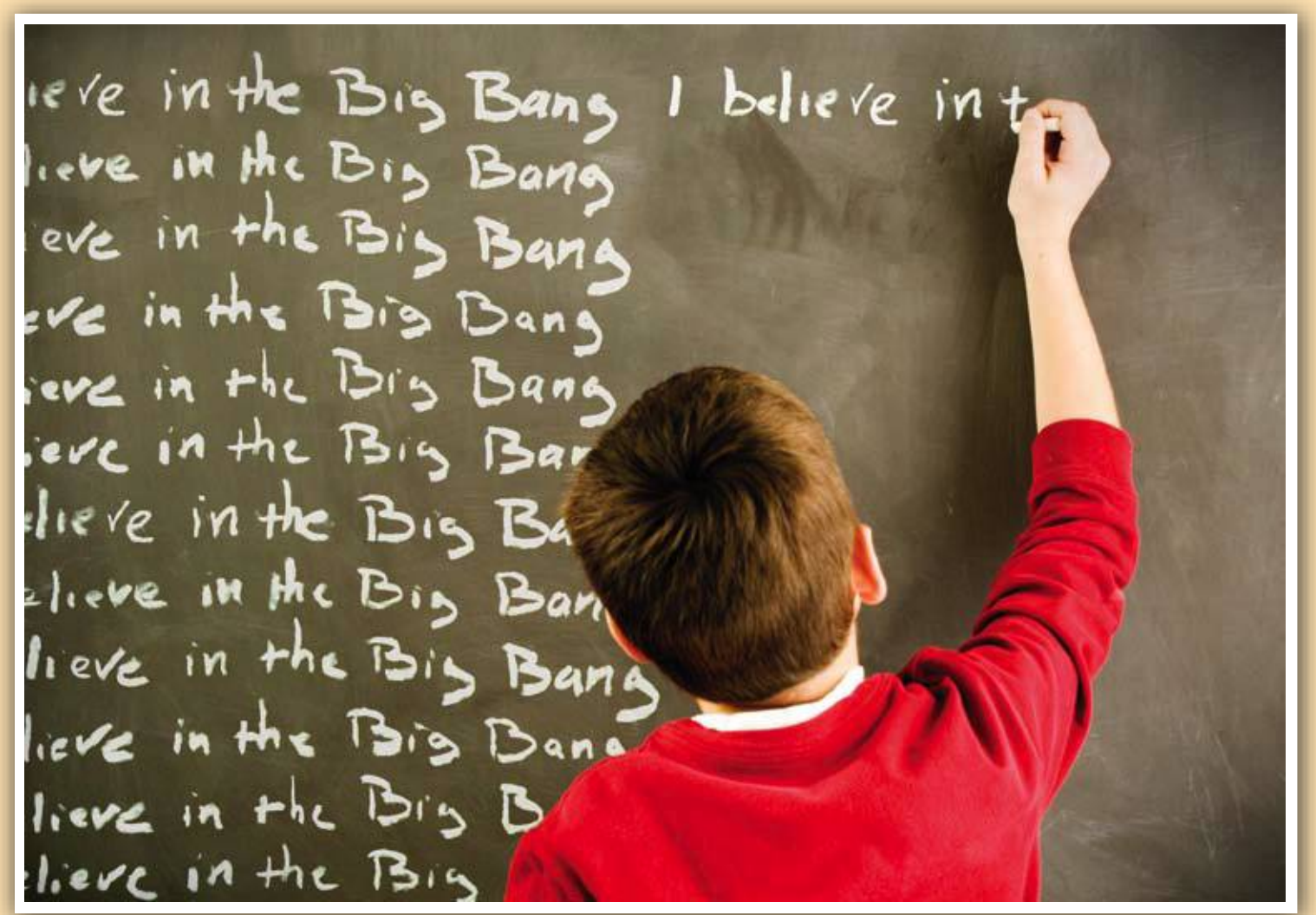
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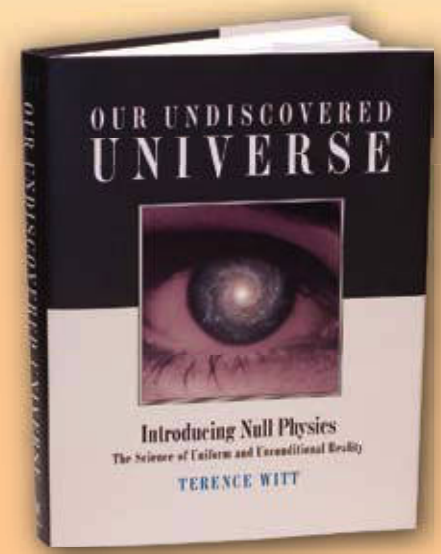

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